DOCUMENT RESUME

ED 388 518 SE 056 709

AUTHOR	Weber, Eldon C.; And Others
TITLE	The Living Soil: Exploring Soil Science and Sustainable Agriculture with Your Guide, The Earthworm. Unit I.
INSTITUTION	Iowa State Univ., Ames. Agricultural Education and Studies Unit.
SPONS AGENCY	Iowa Association of Soil and Water Conservation District, Ames.; Iowa State Univ., Ames. Leopold Center for Sustainable Agriculture.; Resource Enhancement and Protection Conservation Education Board, Des Moines, IA.
PUB DATE	Jun 94
NOTE	142p.; For unit II, see SE 056 710.
AVAILABLE FROM	Agricultural Education Materials Services (AEMS), Agricultural Education and Studies Department, Iowa State University, 217 Curtiss Hall, Ames, IA 50011 ($49 plus shipping, negotiable price when ordering 5 or more).
PUB TYPE	Guides - Classroom Use - Teaching Guides (For Teacher) (052)
EDRS PRICE	MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	*Agricultural Education; Biology; Conservation (Environment); *Ecology; Environmental Education; Hands on Science; *Natural Resources; Science Activities; Science Curriculum; Science Education; Secondary Education; *Soil Conservation; *Soil Science
IDENTIFIERS	*Sustainable Agriculture

ABSTRACT

This instructional packet introduces students to soil biology, ecology, and specific farming practices that promote sustainable agriculture. It helps students to discover the role of earthworms in improving the environment of all other soil-inhabiting organisms and in making the soil more fertile. The activities (classroom as well as outdoor) feature hands-on exercises for participants to gain experience in the association of land management with good soil health. Self-contained background information, activities, visual masters, and some color transparencies are included. The individual instructional exercises can be used independently with units in horticulture, natural resources, ecology, management, soils, livestock systems, and cropping systems. Unit topics include: understanding basic soil biology principles; recognizing the relationship between plants, animals, and the soil; discovering the impact of tillage and nutrient management; discovering the role of earthworms in maintaining good soil health; and exploring earthworm management. Contains 16 references. (JRH)

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ED 388 518

The Living Soil

Exploring Soil Science and Sustainable Agriculture with your guide, The Earthworm

Agricultural Education and Studies
Iowa State University
201 Curtiss Hall
Ames, Iowa, U.S.A. 50011-1050

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The Living Soil

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Published by

Agricultural Education & Studies
201 Curtiss Hall
Iowa State University
Ames, Iowa, U.S.A. 50011-1050
May 1993

Funded by

Leopold Center
for
Sustainable Agriculture
Iowa State University
Ames, Iowa

Supported by

Resource Enhancement
and
Protection Conservation
Education Board
Grimes Building
Des Moines, Iowa

Iowa Association of
Soil and Water
Conservation District
Commissioners
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-- Foreword --

> "It may be doubted if there are any other animals which h e
> played such an important part in the history of the world
> those lowly organized creatures (earthworms)."
>
> Charles Darwin - 1881

Soil sustains life on Earth. But this precious natural resource is in global jeopardy. On every continent, soil erosion alters ecological balance, often with disastrous results for whole populations. In every nation, destructive farming practices rob soil of nutrients, thereby endangering our world food supply.

People have been destroying fertile land for thousands of years. In ancient times empires toppled and entire civilizations perished when soil erosion turned forests into deserts and rich farmlands into dust. Unfortunately, today, centuries later, we are no less endangered by mismanaged land. In every region of the world, there is more destruction to the soil than improvement.

How can we remedy this problem? Is it not, after all, a genuine threat to our global survival?

Our best hope lies with the world's youth and worldwide environmental education. It is time for a global outreach that emphasizes "hands-on" field and classroom studies in natural resource management and agricultural education. Of prime importance in this educational initiative is the need to spread global understanding of soil science and the particular farming practices that have come to be known as "sustainable agriculture."

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Soil science and sustainable agriculture are inextricably related. The knowledge of one is essential to a better understanding of the other. Sustainable agriculture is defined as "an agriculture that is continuously productive and profitable; conserves natural resources and enhances the health and safety of people, domestic animals and wildlife."

Is this an impossible ideal? Not at all. Teaching sustainable agriculture, practicing it and watching land and people prosper because of it, have proven to be fully attainable goals.

Soil, of course, is the very foundation of agriculture. It follows, then, that students well grounded in soil science can contribute much to the world's understanding of sustainable agriculture.

In the United States at Iowa State University, an extraordinary study in support of soil science and sustainable agriculture is underway. At the university's National Soil Tilth Laboratory, soil scientists are researching the creative role of earthworms in the development and health of soil. The scientists are confirming Charles Darwin's discovery that these most humble creatures -- earthworms -- can be mankind's mascots and instructors in learning the attributes of naturally fertile, highly productive soil.

The Iowa scientists are discovering new answers to old questions. What, exactly, makes soil fertile? What degrades soil? What better ways are there to minimize soil erosion? Why are there vast numbers of earthworms in some kinds of soil and almost none in others? By carefully studying earthworm behavior in relation to these and a host of other questions, they are identifying land management practices that increase soil fertility, protect it from erosion, and thereby help assure the long-term productivity of agriculture.

In a word, earthworms are leading the way to a greater understanding of soil science and of ways to manage land for sustainable agriculture!

+ + + + + + +

Innovative educational tools are needed for teachers to effectively involve their students in "hands-on" experiences. The Department of Agricultural Education and Studies at Iowa State University, with support from the Leopold Center for Sustainable Agriculture, has produced a secondary school curriculum that highlights the findings of the National Soil Tilth Laboratory.

In the instructional pages that follow, and in the accompanying videotape, students are introduced to soil biology and ecology, and to specific farming practices that promote sustainable agriculture. In the classroom and during outdoor field exercises, the students work with live earthworms and discover that these diligent burrowers create thousands of miles of tiny tunnels that bring air, water, and enriched organic life to the soil. Earthworms, they see, improve the environment of all other soil-inhabitating organisms, including plant roots.

Most important, they learn that soils made more fertile by earthworms can result in substantially increased crop production and simultaneously lower the need for chemical fertilizers to stimulate plant growth. In turn, water quality improves because fewer chemicals pollute aquifers and streams. Earthworms, then, are a double win-win equation!

Students also discover the amazing world of microorganisms within the soil. They learn that in a single teaspoon of fertile topsoil there are more individual living organisms than there are people on earth, and that the proper combinations of living organisms in an agricultural system can be profitable as well as environmentally sound.

+ + + + + + +

Mechanical tillage varies throughout the world from the use of hoes in some countries to large machines in others. But the earthworms' work is the same everywhere, and their presence is global. In that shallow region only a few inches beneath the surface of the land, earthworms are Nature's master tillers of the soil. Their nearly worldwide presence means that as more people learn to practice sustainable agriculture, many of their concerns will be similar regardless of geographic location.

Clearly, as education for soil science and sustainable agriculture spreads, the earthworm can play a dominant role. Students and teachers are learning that Charles Darwin's friend can be youth's global guide in land management practices that increase food production, improve water quality, lower farming costs, and protect the living soil.

Shirley Foster Fields
Washington, D.C.
May 1993

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The Earthworm Song
Copyright © 1992 Tallents and Fields
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Washington, D.C. 20015

Melody by
Martin Tallents
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The Earthworm song dedicated to:
Iowa State University's Department of
Agricultural Education & Studies by
Martin Tallents and Shirley Foster Fields

Facilities Furnished by
National Soil Tilth Laboratory
Iowa State University, Ames

Chariton Community School
Chariton, Iowa

Ames Senior High School
Ames, Iowa

Hometeam Pizza
Ames, Iowa

Special Thanks to
Chariton Community Agriculture Students
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Vocational Instructional Occupational Competencies Included in this Curriculum

1. Describe basic soil biology principles.
2. Define the role of earthworms and microbes in the soil.
3. Analyze the environmental impact that agricultural practices may have on soil.
4. Explain the impact agriculture has on natural resources and the environment.
5. Analyze/interpret information to make sound management decisions.
6. Follow directions.
7. Utilize equipment correctly.
8. Handle hazardous chemicals and flammable materials correctly.
9. Explain limiting factors of successful plant/crop growth.
10. Explain the balance needed to maintain land use resources.
11. Identify contemporary natural resources issues and concerns.
12. Organize thoughts and clearly express point of view.
13. Use standard units of measure accurately.
14. Use standard soil survey report.
15. Apply/use scientific methods/analysis.
16. Maintain clean and orderly work area.
17. Work effectively with others.

Introduction

The following quotes are not uncommon in a new trend of thinking as we enter the age of "information and communications". The curriculum that follows provides youth with a strong foundation "to take the lead" in this exciting new era.

"Forests, pastures and lawns usually have healthy populations of earthworms..... there are from 240 to 15,550 worms per square yard in Indiana pastures compared to less than 60 in corn/bean fields."

Eileen Kladivko, Soil Scientist
Purdue University
Worms and Water, **Journal of Soil and Water Conservation** November-December 1987

"All wildlife is rooted in the soil. To illustrate, herbivores (plant eaters), such as deer, rabbits, and many insects, thrive on vegetation grown in rich, fertile soils. Freshwater habitats derive their fertility and produce plant life for the herbivores from the soils in the surrounding land or watershed. Even carnivores (flesh eaters), such as marsh hawks, foxes, and smallmouth bass, eat herbivores and are thereby linked to the soil. Fertile soils yield the best crops, whether they are corn, soybeans, deer, or pheasants. Conserving and building soil fertility are basic considerations in managing wildlife."

Fred H. Montogue, Department of Forestry and Natural Resources, *Wildlife Field Notes: All Wildlife is "Rooted" in the Soil*

"Tillage tools discourage earthworm activity. It took three to four years before the worm population was regenerated once heavy tillage stopped. The more they work, the more capillary action their burrowing creates throughout the soil profile. The worms produce an estimated 10,000 pounds of castings per acre annually, building fertility and organic matter. That is especially beneficial to tilth on lighter soils. Earthworm activity conserves moisture for plants and reduced runoff protects against erosion."

Barry Kusel, Carroll County Iowa Farmer
Ten Years of Not Tilling, It Protects The Environment and Your Pocketbook, **Wallaces Farmer** February 1993

"By the end of this century, 80 percent of the cropland will be in residue management. It will be the greatest change in agriculture in 100 years."

Bill Richards, Ohio Farmer and Chief United States Soil Conservation Service, quoted by Hugh Sidey, *Revolution on the Farm*, **Time Magazine** June 1992

"Soil structure is developed with the help of earthworms, the growth of soil roots, and freezing and thawing of water between soil particles (in the absence of soil compaction). Tillage destroys soil structure which leads to soil compaction, soil crusting and sealing of surface pores, and increased water runoff and erosion."

Doug Harford, Illinois Farmer - 1993

"No-till farming is emerging as the greatest agricultural advance of the century in terms of conservation, the environment and productivity. If we do it right, no-till can be the biggest advance since man began husbanding the soil."

Doral Kemper, USDA Agricultural Research Service, Washington D.C. - 1993

The above quotes are representative of the new emphasis in correlating the value of soil health, soil biology, and soil productivity to new concepts in tillage and nutrient management.

Curriculum Background and Instructions

Organization of Materials

Unit I (Subunits a through e) provides an innovative approach to teaching the basic principles of soil biology. This unit, developed during 1992 and 1993 is made available to teachers and educators in 1993. Following is a short summary of each of the Subunits:

Unit I - a Understanding Basic Soil Biology Principles: Includes a video tape and "hands-on" experiences such as a recipe for a *dirt cake*, featuring the "earthworms as your guide" in determining soil health.

Unit I - b Recognizing the Relationships Between Plants, Animals, and the Soil: Helps put in perspective, the essential link (symbiotic relationship) between the living plants and animals both above and below the surface of the earth.

Unit I - c Discovering the Impact of Tillage & Nutrient Management Systems on Soil Health: Focuses on the impact that tillage and nutrient management systems have on soil health through the higher order thinking skills. It applies to the urban or farm setting.

Unit I - d Discovering the Role of Earthworms in Maintaining Good Soil Health: Features the earthworm, with activities to provide opportunities for discovering the characteristics and value of earthworms to all of life.

Unit I - e Exploring Earthworm Management: Provides the teacher with guidance on making earthworm population comparisons under different soil, field, crops, tillage, and nutrient conditions. Allows students to apply concepts presented in Unit a-d.

Succeeding units featuring microorganisms are in the process of development and field testing and will be available in the summer of 1994.

Flexibility in Use

The instructional units contained in this curriculum feature "hands-on" exercises for participants to gain experience in the association of land management (lawn, garden, and farm) with good "soil health". These instructional materials are designed to accommodate busy teachers, allowing for flexible use in several subject matter areas.

Self-contained background information, activities, visual masters, and some color transparencies are included. The individual instructional exercises can be used independently with units in horticulture, natural resources, ecology, management, soils, livestock systems, and cropping systems. Laboratory exercises and small plot demonstrations allow for use with both rural and urban people. The **Agriculture's Impact on The Living Soil Video Tape**

Assisted Instructional Unit is designed as an interest approach to the curriculum, or as a self-contained (stand-alone) short unit. A film strip, **Leopold Center Projects** (including **The Living Soil**) provides an overview of research that can be linked to this curriculum.

Competencies

Many of the competencies included in the instructional exercises address the new Iowa Department of Education vocational competencies.

Format

Background information (including key vocabulary terms) is included for the teacher and can be duplicated for the participants if so desired in the form of information sheets (**INFO-SOIL-1**). Written activities and knowledge builders (evaluation instruments) for participants are contained in activity pages marked (**ACT-SOIL-1**). Laboratory or field exercises marked (**LAB-SOIL-1**) are designed for "hands-on" learning. Visual masters used for transparencies are marked (**VM-SOIL-1**). Two colored transparencies are also included.

Project Background

The **Agriculture's Impact on the Living Soil Video Tape Assisted Instructional Unit** packet was funded by the Resource Enhancement and Protection Program (REAP), Des Moines, Iowa, and is incorporated as an interest approach in this curriculum. The balance of the curriculum was funded by the Leopold Center for Sustainable Agriculture, Iowa State University. The Iowa Association of Soil and Water Conservation District Commissioners (IAWSCDC) supported the development of the curriculum.

Subject Matter Background

Important concepts to consider in sustainable agriculture are:

- √ Control soil erosion and protect water quality
- √ Employ proper nutrient management
- √ Minimize pesticide use
- √ Adapt nutrient and pesticides to soil types
- √ Use lawn, garden, and agricultural wastes as nutrient resources
- √ Select agricultural enterprises to fit capability of soil and water resources
- √ Reduce energy inputs in crop and livestock enterprises
- √ Enhance wildlife habitat

This curriculum allows participants an opportunity to involve many of the above concepts as they relate to the impact of humans on the living soil organisms and the management of organic matter. There is not one system that is right for every person. There are many combinations (practices or systems) as options one can use in developing practical land management activities in harmony with the environment. This curriculum gives participants an opportunity to try some experiments on a small scale to help arrive at some answers that can be adapted to the garden, lawn, or farm.

Soil is a complex resource that needs to be understood, if we are to have a profitable, sustainable, environmentally sound farming enterprise. Farmers who are using some form of reduced tillage (especially no-till) are beginning to understand that the more a soil is worked, the faster it's organic matter will be exhausted. If soils are treated like an interstate highway resulting in compaction of heavy tillage, soil health suffers, with a less favorable environment for plant and animal life; and less net profit.

Managing the soil's organic matter and soil organisms is at the heart of profitable sustainable horticulture and agriculture enterprises. The value of managing living soil organism for a healthy soil has been overlooked by farmers and others involved in agriculture. According to Douglas Karlen, Area Resource Specialist and Soil Scientist at the National Soil Tilth Laboratory in Ames, Iowa, an excellent way to improve soil quality is to leave unharvested plant parts on the ground. The carbon in these materials feeds beneficial bacteria and fungi in the soil that help plants use nitrogen and other nutrients.

The Universe Below

While our attention in the last 40 years has been on space and technology, few people realize the existence of a universe below our feet. Below the surface of the land there is another world to be discovered -- rich; variable in colors, textures, smells, and pulsating life! This underground world, so vital to our existence, is our complex community of living soil organisms. The soil can tell us so much about our present-day environment and the geologic history. It is the home of millions of living things -- a recycling factory for so much of the energy that sustains life.

What a fantastically complex system exists within the soil! Even if we could enter a handful of soil, we would probably not understand it completely. The community of soil creatures that breaks down crop residue is so diverse that almost any organic compound we add to it can be used by other organisms for food. This holds true for proteins, cellulose, and even most pesticides. Managing soil life gives us long-term agronomic stability -- as well as some of the fertility for next year's crop. The two great enemies of soil organic matter are erosion and excessive tillage.

The world below the surface of the earth is teeming with life, much of which is unknown to most of us. Every acre of soil is home to two or more tons of living things -- earthworms, insects, bacteria, fungi, and other living organisms. All of these living organisms are dependent on interrelated activity. Day and night, the living creatures work together to build, enrich, and restructure the soil.

Earthworm as the Master Builder

Among all performers in the living soil, the earthworm is the superstar. Aristotle called earthworms the intestines of the Earth. Charles Darwin wrote, "It may be doubted whether there are any other animals that have played such an important part in the history of the world as these organized, lowly creatures." Food is a major factor in our lives. All the necessities, comforts, satisfactions, and luxuries wait upon the production of food which comes primarily from topsoil. As a master-builder of topsoil throughout the ages, the earthworm in nature has played and continues to play a leading role. Our strengthened respect for this basic fact and our watchful examination of earthworm behavior can help protect topsoil and our world food supply.

Home of the Living Soil Community

Let's enter the living soil community. Soils consist of five key components: mineral particles, air, water, organic matter, and living organisms. What makes for a good home for soil organisms? An ideal community for the important animal life is a soil structure that will provide for 25% air, 25% water, (50% pore space), 45% mineral, and 5% organic matter or humus. Soil humus is the remains of organic matter after it has undergone various states of decomposition by microorganisms. Humus is the more stable by-product of decomposition. The nutrients held in humus are largely unavailable to plants. Nutrients are released primarily as a result of fungal and bacterial decomposition and then earthworms mix the nutrients into the soil through their burrowing.

The cover over this community, called the O horizon in a soil profile, is comprised of dead plant and animal materials. Topsoil, the A horizon, is the upper soil layer containing plant roots, bacteria, fungi, earthworms, small animals etc. It contains high organic matter and is darkest in color. The soil beneath (subsoil), the B horizon, is the middle soil layer which usually contains higher clay content. It has fewer organisms and less organic matter. Plants usually don't grow as well in it. The C horizon is the lowest soil layer. It is less altered and weathered than the layers above and it contains less living matter. It may be called the parent

material. It gets this name because it is the weathered rock and partly weathered soil from which the soil layers above were formed.

Organic matter gives soil its good tilth, a sponge-like quality. It helps to make the whole soil mass more porous allowing for better water infiltration and air penetration. Soil tilth is a management term that refers directly to the soil's physical properties and how they affect its capacity to support plant growth. An ideal soil organism community as described above is sometimes thought of in terms of good soil tilth. Soil tilth is very important in crop production.

A soil in good tilth breaks up easily into crumbs or granules about the size of wheat grains or soybeans. The crumbs are porous. They are made up of tiny bits of soil linked together something like popcorn in a popcorn ball. They hold together even when soaked with water. Intensive cultivation destroys soil structure because it lowers the total pore space of soils. Loam and silt loam refers to soils that have a favorable proportion of sand, silt, and clay (best suited to crops and an ideal home for soil organisms).

Perspective on a Global Scale

Hans Hurni, President of the World Association of Soil and Water Conservation, in an article *The Soil as a Living Resource* stated, "Never in historical times has the soil been more threatened by degradation and irreversible destruction on a global scale than in this century. Although much was done to preserve and restore it, the destructive processes are accelerating more rapidly than the restorative efforts carried out by numerous farmers, experts, planners, researchers -- in short, people like us."

It is hoped that this curriculum will stimulate greater global interest, understanding, and sensitivity about ways to manage both urban and rural lands in harmony with the living soil environment. The curriculum was developed in Ames, Iowa, the heartland of America, but its teachings are relevant in all fifty states of the United States and in countries throughout the world.

Unit I - a
Understanding Basic Soil Biology Principles

Introduction

The soil is a place where innumerable different types of plants and microorganisms live. The majority of these living organisms are so small that it is impossible to see them without a microscope. Life within the soil has a major impact on soil tilth (health) by helping incorporate organic matter, forming water-stable aggregates, increasing the availability of nutrients to plants, increasing soil drainage, and improving aeration. At the heart of our most valuable natural resource, the soil, the presence of earthworms serve as an indicator of soil health.

Objective

Participants will be able to recognize the soil as a living matter through the use of demonstrations and a video tape.

Competencies

1. Describe basic soil biology principles.
2. Define the role of earthworms in the soil.
3. Explain the impact agriculture has on natural resources and the environment.
4. Follow directions, organize thoughts, and clearly express point of view.

Materials

1. Ingredients and suitable props for ISU Dirt Cake.
2. Small quantity of soil.
3. **Agriculture's Impact on The Living Soil** video tape (13:40).

Information

INFO-SOIL-1 Who Wrote *The Earthworm Song*?
INFO-SOIL-2 *The Earthworm Song*
INFO-SOIL-3 Vocabulary Builder

Activities

ACT-SOIL-1 What's Cooking in the Kitchen?
ACT-SOIL-2 Video Key Points
ACT-SOIL-3 Vocabulary Challenger
ACT-SOIL-4 Knowledge Builder

Visual Master

VM-SOIL-1 Summary Unit I - a

Teaching Procedure

1. Use the **Interest Approach** Part A and B to make participants aware of soil's importance.

Interest Approach Part A

Relate to participants the following information provided by the National Soil Tilth Laboratory, Iowa State University.

> In the field lab "kitchens", Iowa State University and United States Department of Agriculture researchers are working on "recipes" for better understanding and preservation of soil. For proper soil tilth: Prepare soil starter kit. Stir in microbes, plants, and animals. Add organic matter. Splash on water; not too wet or dry. Set timer for 2 to 5 years, then begin to see results. A good batch will be dark, rich, and crumbly. Top with crops. Serves one planet.

Prepare an ISU Dirt Cake before class and serve during class. As participants are consuming the "**Interest Approach**"; ask: "How does the dirt cake compare to soil?" *It is made up in layers like soil, contains (gummy) worms and plants, and is available in limited quantities.* Ask, "Why is soil important?" *We depend upon it for our survival.* Ask, "Is soil an unlimited natural resource?" *No, because it takes a long time to regenerate new soil.*

ISU Dirt Cake

1 medium flower pot
24 oz. chocolate sandwich cookies
1 cup powdered sugar
8 oz. cream cheese
2 3-oz. boxes instant chocolate pudding
2 cups milk
1 12-oz. tub whipped topping
1 package gummy worms candy
Crush cookies; set aside
Mix powdered sugar and cream cheese; set aside
Mix instant chocolate pudding and milk, then blend with whipped topping
In flower pot, layer the three mixtures, saving some cookie mix for topping
Place gummy worms into "dirt" on top
Chill, add flowers, or other decorations
May be served with trowel or sand shovel

Provide participants with **ACT-SOIL-1**. Instruct participants to write a paragraph explaining the similarity between the two recipes. Have participants share their paragraph with the group.

Read the following information aloud while a participant completes **Part B** of the **Interest Approach**.

Interest Approach Part B

Pick up a handful of soil and notice how it feels and looks. The soil you hold in your hand is a complex mixture of inorganic minerals (mostly clay, silt, and sand), decaying organic matter, water, air, and living organisms. Imagine the soil you hold is the earth's surface. **Drop** three-fourths of it back on the ground. The amount dropped represents how much of the earth is covered by oceans, rivers, and lakes. The remaining soil represents the land. **Drop** one-half of the remaining soil from your hand. The amount dropped represents the desert regions, glacial poles, and mountain peaks where many things won't grow. **Drop** one-tenth of the remaining soil from your hand. The amount dropped represents the land where people live -- cities, towns, houses, schools, roads, and parking lots. The soil left in your hand represents all the soil we have to support life on earth. The earth's thin layer of soil (at most only a meter or two thick) provides nutrients for plants which directly or indirectly provide the food we and other animals use to stay alive and healthy.

Ask participants, "Why is the remaining soil vital for our existence?" Discuss their answers.

2. Ask each participant to write one sentence on what soil biology means to them and another sentence explaining what kind of environment an earthworm likes. Have participants share their sentences.

3. Provide a copy of **INFO-SOIL-1**, (Who Wrote the Earthworm Song?) and **INFO-SOIL-2** (*The Earthworm Song*) to participants. Discuss the message contained in the song lyrics. Review **ACT-SOIL-2** (Video Keypoints) to identify key points participants need to find while viewing **Agriculture's Impact on the Living Soil** video tape.

4. Show the video tape, **Agriculture's Impact on the Living Soil** (13:40).

5. Immediately after viewing the video tape, ask each participant to again write one sentence on what soil biology means to them and another sentence explaining what kind of environment an earthworm likes. Have participants compare their first two sentences with their last two. Have participants share the differences. Instruct participants to complete **ACT-SOIL-2** and then discuss the key points contained in the video tape.

   Q1. The earth is a complex network of living things made up of communities that are dependent on each other for survival. How does this relate to the living soil?

A1. The living soil is made up of many small communities (microbes, earthworms, animals, etc.) and all play a vital part in helping to maintain soil quality (health).

Q2. Understanding the importance of better land management and how it relates to the environment beneath the ground directly affects soil quality (health). Explain why.

A2. By using the correct land management practices, we can protect and enhance our soil. These practices help maintain a suitable underground environment for the life that lives there. This life (microbes, earthworms, animals, etc.) helps in the breakdown of organic matter into usable nutrients.

Q3. Why is soil earth's most valuable resource?

A3. The earth's thin layer of soil provides nutrients for plants which directly or indirectly provide the food we and other animals use to stay alive and healthy. The process of rebuilding soil is a lengthy process.

Q4. Why are earthworms an indicator of good quality soil?

A4. If you have high numbers of earthworms, the soil conditions are suitable for other organisms. Microorganisms along with earthworms are needed for residue breakdown. Large numbers of earthworms help improve soil tilth with their burrowing.

Q5. What management practices are needed to maintain earthworm numbers? Why?

A5. Soil management practices may include reduced or conservation tillage, conservation practices, erosion control, and residue management. Insect management practices may include limited use of insecticides, integrated pest management (IPM), crop rotations, and chemical management. Plant management may include cropping systems and nutrient management. These management factors help promote healthy soil which maintain a stable environment for earthworms and microbes to live.

Q6. How well do people understand the importance of soil organisms?

A6. People do not fully realize that soil microorganisms help make soil productive and are one of the factors that make earth soil different from the moon "soil."

Q7. Is the living soil as important in one part of the world as another? Why?

A7. Where ever we are in the world, soil is the key link between plants and animals. The living organisms that make up the soil are the recycling process, key to providing food for plants and the plants provide food for animals.

Q8. What is the message contained in *The Earthworm Song* lyrics?

A8. Earthworms help maintain our healthy, fertile soil. Earthworm burrows bring air and water underground for plant use. Other organisms in the soil help maintain quality soil.

Q9. What do all countries around the world have in common with regard to the "Living Soil" as shown in the video tape?

A9. Every country depends on the soil for the production of food. The soils around the world contains similar living things which play an important part in maintaining soil health.

Q10. What does the statement "There is strength in diversity mean to you?" After watching the video tape, rethink this question. Did it broaden your answer? How?

A10. Diversity was shown in the video tape ranging from bees, elephants, earthworms, and a discussion on the value of microorganisms. All have a special function within the communities on earth. Differences were shown in people, nationalities, cultures, and abilities, who rely on one another for their talents and strengths. Sustainable agriculture accomplished through the proper combinations of living organisms in an agricultural system, can be profitable, as well as, environmentally sound in the development of our natural resources.

6. Use **INFO-SOIL-3** (Vocabulary Builder) to review key terms for this unit.

7. Use **VM-SOIL-1** to summarize Unit I - a.

VM-SOIL-1

The earth is a complex network of living things made up of communities that are dependent on each other for survival.

Understanding the importance of better land management and how it relates to the environment beneath the ground directly affects soil quality.

Earthworms are an indicator of good quality soil.

8. Use **ACT-SOIL-3** (Vocabulary Challenger) to review key terms used in the unit.

Across: 1. reduced 3. chemical 6. organisms
Down: 1. rotation 2. microbes 4. ipm 5. tilth 7. sustainable

9. Use **ACT-SOIL-4** (Knowledge Builder) for Unit I-a summary or evaluation.

Q1. Match the following terms with their correct definitions.

A1. (d) Soil Tilth
(c) Microbes
(e) Reduced or Conservation Tillage
(g) Chemical Management
(f) Integrated Pest Management
(a) Soil Organisms
(b) Sustainable Agriculture
(h) Crop Rotation

Q2. What is an indicator of good soil health?

A2. Good earthworm and microorganism populations.

Q3. What benefits do good earthworm and microorganism populations provide?

A3. Increases water infiltration and air penetration, improves soil structure, and helps break down organic matter.

Q4. Why should farmers use reduced tillage or no-till?

A4. Less tillage protects soil from erosion and allows earthworms to not be disturbed.

Q5. What is the food source for earthworms?

A5. Surface residue or decaying plant material.

Q6. Explain how earthworms provide habitat for other soil animals.

A6. Earthworm burrows provide homes for insects and other soil organisms.

Q7. Why is it important to use soil management practices?

A7. It is important to protect the health of the soil which is vital for human life.

Answers for questions 8 - 10 will vary.

Q8. What can farmers do to improve soil health?

Q9. What new laws are needed to improve soil health? Write an example.

Q10. What can students do to help improve soil health?

Who Wrote the Earthworm Song?

"A labor of delight" is the way three people from three nations describe their teamwork in writing the music and words for *The Earthworm Song*. When the trio -- **Martin Tallents**, **Shirley Foster Fields**, and **Michael Shefrin** -- first met on the Spanish Island of Mallorca, they discovered a common bond, their love for the beauty and hope for the health of Planet Earth. They wrote their song of homage to the earthworm in the hope that it will strengthen world understanding of this humble creature's extraordinary role in protecting the soil upon which all life depends.

Martin Tallents, British songwriter, poet, and horticulturist wrote the music and together with Shirley Foster Fields, the words to *The Earthworm Song*. Since 1969, Tallents has lived eleven months of each year in the village of Deya on the Spanish Island of Mallorca beside the Mediterranean Sea. He returns to his home in London for one month each year. He is a graduate of Trinity College, Cambridge, and past president of England's Sutton-at-Hone Horticultural Society and the Boxley Heath Rose Society.

Tallents was five times decorated by the British Navy for valor as a lieutenant on mine-sweeping convoys at Malta and the Normandy Invasion during the Second World War. He attributes his post-war return to health to the three years he worked as a farm laborer on the land in England.

Today, at his small stone house in Deya, Tallents is host to an international community of artists, musicians, and poets. Many afternoons he has four o'clock "Open House" for English tea. Local children are his guests and so are actor Michael Douglas and his wife Diandra, who have a seaside estate nearby. Tallents makes guest appearances on Spanish television. He has written more than seventy songs. He is donating his financial remuneration from *The Earthworm Song* to a scholarship fund for agricultural students at Iowa State University. This, he says, is his payment of a debt of gratitude for health restored as a farmhand on the land.

Shirley Foster Fields, all-media writer and producer/director of national campaigns for natural resource conservation, is founder and president of her own public relations firm, **Fields and Farmers International**. She works on behalf of global environmental education, farmers, farmland, and sustainable agriculture.

Fields was public information officer for the Soil Conservation Service (SCS), United States Department of Agriculture, Washington, D.C. from 1972 to 1992. On special assignment for SCS, she served as Director of Information for the National Agricultural Lands Study (NALS) at the Executive Office of the President, the White House, from 1979 to 1981. The purpose of the study, co-chaired by the Secretary of Agriculture and the Chairman of the Council on Environmental Quality (CEQ) was to determine the extent of the conversion of America's farmland to non-agricultural use, and ways to protect the land from further unnecessary loss. Fields' mentor is Thomas Paine. Her pamphlet, *Where Have the Farmlands Gone?*, was featured on national network television and quoted in virtually every daily newspaper in the United States.

Fields is a former European Correspondent for United Press International, staff reporter for the Dallas (Texas) Morning News, and Director of Public Relations for the Society of American Florists, the U.S. flower industry's national trade association. Born in California and reared in Connecticut, her Alma Mater is the University of Missouri Journalism School. She has traveled in forty-two countries and lived in seven. She lives in Washington, D.C.

Michael Shefrin is a classical guitarist and jazz musician, born in Massachusetts and educated in New York City. He has made his home in the village of Deya, Mallorca, Spain, since 1983. Shefrin began his guitar studies when he was ten years old after hearing a Beatles record. In 1977, he graduated from Berklee College of Music, Boston, Massachusetts. He has worked with many jazz groups, including "Wild Bill Davis", the former organist for Count Basie and Duke Ellington. Shefrin has transcribed numerous works for the guitar's repertoire. He gives evening concerts on Mallorca.

Prepared by Shirley Foster Fields, Washington, D.C. 1993.

The Earthworm Song

Introduction

Have you heard?
And do you know?
Who is your best friend?
It may come as some surprise,
But on him you depend.
He works nights on your behalf
Cleaning up the earth,
When all mankind is fast asleep
That's when he shows his worth.

Chorus

Earthworm, Earthworm,
Greatest friend of man,
Tireless worker,
Since the earth began.

Earthworm, Earthworm,
Tunnelling through the nights,
Nature's champion,
Setting earth to rights.

Verse

Ancient lands are deserts now,
Cos few men understood
How and why the earthworm's work
Keeps earth green and good.

Our life depends on what will grow
In healthy, fertile soil,
But soil might all be washed away
Without the earthworm's toil.

So, earthworm, come and take a bow!
We know your priceless value now.
The holes you're digging catch the rain
So seeds can root and sprout again.

Yes, earthworm, stand and take that bow!
Without you there'd be quite a row.
There'd be less breakfast,
There'd be less lunch,
There'd be less goodies for us to munch.
Small wonder, you're the friend of man.
You've been at work since life began!

Chorus

Earthworm, Earthworm,
Greatest friend of man,
Tireless worker,
Since the earth began.

Earthworm, Earthworm,
Tunnelling through the nights,
Nature's champion,
Setting earth to rights.

Verse

With a wiggle and a wriggle
And a push right through,
The earthworm's got so much to do
His tunnels bring air
And water underground
So the roots of plants can grow up sound.

Other lively creatures
Are working underground.
Moles'n millipedes,
Snakes and snails abound.
There are badgers and beetles,
And earwigs and ants,
Working all together
In a soil-building dance.

Finale

Mothers call it mud on washday,
Farmers call it soil;
But our earth is green and glorious,
Thanks to the earthworm's toil.

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Vocabulary Builder
Unit I - a

Chemical Management - The correct handling, application and disposal of agricultural, lawn, garden, or household chemicals and their containers as to not harm the environment.

Crop Rotation - The growing of a sequence of crops, alternating each year so as to break up insect cycles and increase natural fixation of nitrogen. Example: corn, oats, alfalfa with alfalfa being the nitrogen fixing (manufacturing) plant.

Integrated Pest Management - An ecological approach to managing pests using pesticides only when and where necessary to reduce economic losses and minimize adverse side effects.

Microbes (microorganisms) - Living creatures so small they can only be seen through a microscope (bacteria, fungi, actinomycete).

Reduced or Conservation Tillage - A tillage system where a portion of the previous year's plant residue is left on the surface after planting seeds. The residue is food for earthworms and less tillage means less disturbing of earthworm burrows and their food supply.

Soil Organisms - Living creatures -- earthworms, microorganisms, and insects -- that live in the soil.

Soil Tilth - Refers directly to the soil's physical properties and how they affect its capacity to support plant growth (sizes of mineral particles known as a soil's texture; their structural arrangement or aggregation, and amounts and forms of organic matter).

Sustainable Agriculture - Profitable cropping and livestock systems that will sustain the soil and water resources and maintain a quality environment.

Reduced or Conservation Tillage. Photo by Soil Conservation Service

What's Cooking in the Kitchen?

Introduction

In the field lab "kitchen", Iowa State University and the United States Department of Agriculture researchers are working on "recipes" for a better understanding and preservation of soil.

Soil Tilth...From Scratch

Ingredients: Soil Starter Kit (sand, silt, clay), Organic Matter, Microbes, Plants, Water, Animals, Time.

For soil tilth (soil health), prepare a soil starter kit. Stir in microbes, plants, and animals. Add organic matter. Splash on water; not too wet or dry. Set timer for 2-5 years, then begin to see the results. A good batch will be dark, rich, and crumbly. Top with crops. Serves one planet.

ISU Dirt Cake

ISU Dirt Cake

1 medium flower pot
24 oz. chocolate sandwich cookies
1 cup powdered sugar
8 oz. cream cheese
2 3-oz. boxes instant chocolate pudding
2 cups milk
1 12-oz. tub whipped topping
1 package gummy worms candy
Crush cookies; set aside
Mix powdered sugar and cream cheese; set aside
Mix instant chocolate pudding and milk, then blend with whipped topping
In flower pot, layer the three mixtures, saving some cookie mix for topping
Place gummy worms into "dirt" on top
Chill, add flowers, or other decorations
May be served with trowel or sand shovel

Instructions

Compare the ingredients of both recipes. Explain how they are similar. Why is soil tilth (health) vital for our existence?

Source: National Soil Tilth Laboratory, Iowa State University, 2150 Pammel Drive, Ames, Iowa 50011.
Prepared by Dr. Gaylan G. Scofield, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. April 1993

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Agriculture's Impact on the Living Soil

Video Key Points

Instructions

Review the following questions before watching the video tape. As you watch the video, make note on this sheet, information needed to answer these questions. This information will be used during the discussion after viewing the video.

1. The earth is a complex network of living things made up of communities that are dependent on each other for survival. How does this relate to the living soil?

2. Understanding the importance of better land management and how it relates to the environment beneath the ground directly affects soil health and quality. Explain why.

3. Why is soil the earth's most valuable resource?

4. Why are earthworms an indicator of good soil quality?

5. What management practices are needed to maintain earthworm numbers? Why?

6. How well do people understand the importance of soil microorganisms?

7. Is the living soil as important in one part of the world as another? Why?

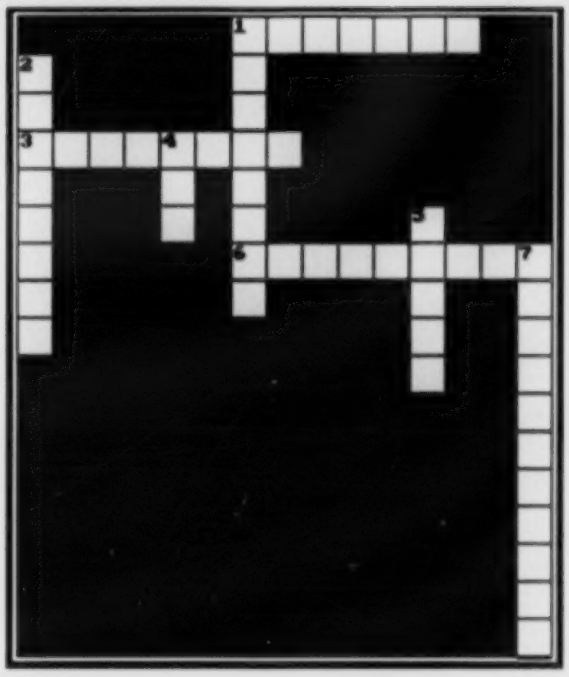
8. What is the message contained in *The Earthworm Song* lyrics?

9. What do all countries around the world have in common in regard to the "Living Soil" as shown in the video?

10. What does the statement "There is strength in diversity mean to you?" After watching the video tape, rethink this question. Did it broaden your answer? How?

Prepared by Dr. Gaylan G. Scofield, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. February 1992

Vocabulary Challenger Unit I-a



Across:

1. _____ tillage is a system of leaving part of the previous years residue on the surface after planting.
3. _____ management is the correct handling, application, and disposal of pesticides.
6. Soil _____ are living creatures that live in the soil.

Down:

1. Crop _____ is the growing sequence of corn, soybeans, alfalfa, oats.
2. Living creatures so small they can only be seen through a microscope (bacteria, fungi).
4. An ecological approach to managing pests using pesticides only when and where necessary to reduce economic losses and minimize adverse side effects.
5. Soil _____ refers directly to the soil's physical properties and how they affect its capacity to support growth.
7. _____ agriculture is the profitable cropping and livestock system that will sustain the soil and water resources and maintain a quality environment.

Prepared by Annette Kiefer, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. May 1993.

Knowledge Builder
Unit I - a

Instructions

Carefully read the following questions before answering.

1. Match the following terms with their correct definitions.

___ Soil Tilth	___ Microbes
___ Reduced or Conservation Tillage	___ Integrated Pest Management
___ Soil Organisms	___ Sustainable Agriculture
___ Chemical Management	___ Crop Rotation

a. Living creatures -- earthworms, microorganisms, and insects -- that live in the soil.

b. Profitable cropping and livestock systems that will sustain the soil and water resources and maintain a quality environment.

c. Living creatures so small they can only be seen through a microscope (bacteria, fungi, actinomycete).

d. Refers directly to the soil's physical properties and how they affect its capacity to support plant growth (sizes of mineral particles known as a soil's texture; their structural arrangement or aggregation, and amounts and forms of organic matter).

e. A tillage system where a portion of the previous year's plant residue is left on the surface after planting seeds.

f. An ecological approach to managing pests using pesticides only when and where necessary to reduce economic looses and minimize adverse side effects.

g. The correct handling, application and disposal of agricultural, lawn, garden, or household chemicals and their containers as to not harm the environment.

h. The growing of a sequence of crops, alternating each year so as to break up insect cycles and increase natural fixation of nitrogen. Example: corn, oats, alfalfa with alfalfa being the nitrogen fixing (manufacturing) plant.

2. What is an indicator of good soil health?

3. What benefits do good earthworm and microorganism populations provide?

4. Why should farmers use reduced tillage or no-till?

5. What is the food source for earthworms?

6. Explain how earthworms provide habitat for other soil organisms.

7. Why is it important to use soil management practices?

8. What can farmers do to improve soil health?

9. What new laws are needed to improve soil health? Write an example.

10. What can students do to help improve soil health?

Summary

- √ **The earth is a complex network of living things made up of communities that are dependent on each other for survival**

- √ **Understanding the importance of better land management and how it relates to the environment beneath the ground directly affects soil quality**

- √ **Earthworms are an indicator of good quality soil**

Prepared by Dr. Gaylan G. Scofield, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. March 1993.

Unit I - b
Recognizing the Relationships Between Plants, Animals, and the Soil

Introduction

There are many benefits to having active life under the land's surface. Soil organisms break down surface residue, help develop fertile soil, increase aeration, and increase water infiltration in the soil.

Objective

Participants will understand the importance of the soil ecosystem and become actively involved in demonstrating and observing plant, animal, and soil interaction.

Competencies

1. Discuss plant, animal, and soil interaction.
2. Describe the nutrient cycle.
3. Plan, analyze, and explain a farming system concept.
4. Analyze the environmental impact that management practices may have on soil.
5. Explain the impact agriculture has on natural resources and the environment.

Materials

1. News print and markers.

Information

INFO-SOIL-4 Vocabulary Builder
INFO-SOIL-5 Common Soil Burrowing Animals
INFO-SOIL-6 Meeting the Needs
INFO-SOIL-7 Nature's Soil Factory

Activity

ACT-SOIL-5 Interactions Between Plants, Animals, and Soil
ACT-SOIL-6 Rotational Farming System
ACT-SOIL-7 Soil Builder
ACT-SOIL-8 Vocabulary Challenger
ACT-SOIL-9 Knowledge Builder

Visual Masters

VM-SOIL-2 Soil Ecosystem (color) & information/activity sheet
VM-SOIL-3 Nutrient Cycle
VM-SOIL-4 Soil Profile (color) & information/activity sheet
VM-SOIL-5 Summary Unit I - b

Teaching Procedure

1. As an **Interest Approach**, ask participants to identify the interactions between a cow, grass, and the soil. Direct participants in discovering how each supports the other and how one depends upon the other. Review **INFO-SOIL-4** (Vocabulary Builder) to familiarize participants with key terms used in this unit.

2. Use **VM-SOIL-2** (Soil Ecosystem - color) to display the soil ecosystem. Soil Ecosystem Information & Activities sheet may be reproduce and given to participants as an informational and activity sheet or used by the teacher in discussion of the soil ecosystem with activities assigned from it. Ask participants to identify visible plant and animal life in the soil. Ask "How do plants and animals use the soil?" Discuss their answers. Ask "How do plants and animals help the soil?" Discuss their answers. Define the term "Soil Ecosystems" using **VM-SOIL-2**. Explain that soil provides a home and food supply for many animals.

3. Provide a copy of **INFO-SOIL-5** (Common Soil Burrowing Animals) to participants. Ask "Are voles, moles, and pocket gophers important and if so why?" Discuss their answers. Discuss why plant and animal life in the soil is important.

4. Use **VM-SOIL-3** (Nutrient Cycle) to discuss the nutrient cycle process. Refer to Soil Ecosystem Information & Activities sheet.

5. Instruct participants to complete **ACT-SOIL-5** (Interactions Between Plants, Animals, and the Soil) which emphasizes the relationship between plants, animals, and the soil. Ask participants to share their work with the group.

6. Use **VM-SOIL-4** (Soil Profile - color) to emphasize the above ground activity and how it can affect below ground activity. Note how the plant roots have penetrated the soil with the greatest amount of organic matter near the surface. The Soil Profile Information & Activities sheet may be reproduced and given to participants as an informational and activity sheet or used by the teacher in discussion of the soil profile with activities assigned from it.

7. Refer to **VM-SOIL-2** (Soil Ecosystem - color) to explain "symbiosis", the living together in close association of dissimilar organisms, especially when mutually beneficial. Ask "How does nitrogen get from the air to the soil?" An example of an important symbiotic relationship is legumes, such as soybeans or alfalfa. The plants need the animal life (nitrogen fixing bacteria in the root nodules) and the bacteria need the plant nodules to complete their process of nitrogen fixation from the air.

8. Divide participants into teams and direct each team to select a piece of land (farm, forest, yard, pasture, garden, etc.) and draw a nutrient cycle for their site on newsprint. Ask each team to explain their work to the group. Use **VM-SOIL-3** (Nutrient Cycle) to emphasize the role of the sun, water, air, and plant growth in the nutrient cycle.

9. Use **ACT-SOIL-6** (Rotational Farming System) to introduce the concept of a "rotational farming system". Ask participants "How do plants in the system meet the needs of animals?" "How do animals meet the needs of plants?" "What are the relationships between plants and animals and the soil?" Emphasize that elements in the system are dynamic and interactive and that if planned correctly, all needs of the system will be met.

10. Review **INFO-SOIL-6** (Meeting the Needs) to illustrate an example of one Iowa farmer's rotational farming system. Divide participants into small groups to complete **ACT-SOIL-7** (Soil Builder). Have each group record their answers on newsprint and then share their answers. Locate a piece of land to experiment with your favorite combination and carry out your own experiment. Is your experiment feasible on a larger scale?

10. Use **INFO-SOIL-7** (Nature's Soil Factory) to illustrate how farming systems (plant and animal activity on the soil surface) affect life in the soil. Emphasize that the living things (earthworms, microorganisms, bacteria, insects, arthropods, fungi, and nematodes) in the soil will be the focus of our study for a period of time. Special attention will be given to how living things in the soil (soil biology) relates to a sustainable agriculture and quality environment.

11. Use **ACT-SOIL-8** (Vocabulary Challenger) to review key terms in this unit.

    Across: 3. aeration 4. mites 6. leach 8. hogged down 9. fauna 11. profile 13. ecosystem 15. beetles 16. organic matter

    Down: 1. bacteria 2. forages 3. arthropods 4. microarthropods 5. springtails 8. humus 10. nutrients 12. fungi 14. flora

12. Use **VM-SOIL-5** (Summary Unit I-b) to relate the following conclusions to participants. The soil is full of life (plants, animals, and microscopic organisms). This soil life plays an important role in the decomposition of organic matter which returns nutrients to the soil (nutrient cycle).

13. Use **ACT-SOIL-9** (Knowledge Builder) for Unit I-b summary or evaluation.

    Q1. Match the following terms with their correct definitions.

    A1.
    - i aeration
    - l arthropods
    - d bacteria
    - e forages
    - m fungi
    - f hogged down
    - k humus
    - g leach
    - o legume
    - j microarthropods
    - p mites, springtails, beetles, millipedes
    - c nutrient cycle
    - o organic matter
    - b soil ecosystem
    - n soil fauna
    - r soil flora
    - h soil profile
    - a symbiosis

Q2. Explain the relationship between the three elements of the ecosystem.

A2. The entire system of life and its environmental and geographical factors that influence all life (including the plants, animals, and the environmental factors) that interact with each other.

Q3. Draw and explain the nutrient cycle.

A3. The circulation of nutrient elements and compounds in and among the soil, parent rock, streams, plants, animals, and atmosphere.

Q4. Explain why it is important to plan farming systems to resemble natural processes.

A4. Farming systems directly affect our soil environment. We depend upon soil for our very existence and the natural process can be profitable and environmentally sound.

Vocabulary Builder
Unit I - b

Aeration - Providing small passageways for air to filter through the soil.

Arthropods - Invertebrate organisms including insects having a segmented external covering and jointed limbs.

Bacteria - Most numerous, extremely small, single cell organisms -- some bacteria provide a mucus that binds soil particles together.

Forages - Legume and/or grass feed for livestock.

Fungi - A group of simple plants without chlorophyll that may be linked together in long filaments called hyphae which help decompose organic matter.

Hogged Down - Allowing livestock to harvest standing crops (hogs in standing corn). This reduces cost and time in harvesting and eliminates storage.

Humus - Decomposed organic matter processed by living soil organisms.

Leach - Movement of dissolved chemicals through the soil profile.

Legume - Nitrogen fixing plant (alfalfa, clover, soybeans).

Microarthropods - Invertebrate organisms (arthropods) that can be seen, but more easily identified under a microscope.

Mites, Springtails, Beetles, Millipedes - Soil animals which chew plant litter into smaller pieces more suitable for micro-organisms to feed on.

Nutrient Cycle - Through the recycling (decomposing) of organic matter (plant and animal) living organisms convert nutrients into a form usable for plants.

Organic Matter - Plant and animal remains at various stages of decomposition.

Soil Ecosystem - A system in which plants and animals inhabit the same location.

Soil Fauna - Animal related soil organisms -- microarthropods, insects, earthworms.

Soil Flora - Plant related soil organisms -- fungi, yeasts, molds, smuts, mushrooms.

Soil Profile - A vertical section of soil showing all of the horizons.

Symbiosis - The living together (dependent on each other) of dissimilar organisms. Example: alfalfa root nodules need nitrogen fixing bacteria and the bacteria need the plant root nodules.

Common Soil Burrowing Animals

Many animals, from tiny nematodes to larger animals like badgers, moles, and voles, make their home in the soil. Not all soil burrowing animals are beneficial with regard to their soil mixing characteristics. Some are damaging to crops.

The greatest number of burrowing animals (mammals) are rodents. Soil that is undisturbed (pastures, forests, prairie, lawns) provides a better animal habitat. This digging, like that of ants and earthworms, alters soil by mixing the layers. Mixing offsets, to some degree, the natural soil aging process in which clay particles and nutrients leach into the B horizon. The digging (mixing) has the effect of rejuvenating the soil. These animals whose homebuilding skills could put to shame many a do-it-yourselfer armed with the latest power tools. Underground dwellers (woodchuck, fox, chipmunk, badger, prairie dog, many insects, and some spiders) dig, tunnel, or burrow very efficiently.

Moles belong to a group of primitive mammals including shrews. They live most of their lives underground in which they have adapted physically. They have an elongated head with a pointed snout; no ears; tiny eyes that can only distinguish light from dark; and large front feet and claws for digging. They are active all year long (near the surface in spring and fall and deeper in permanent tunnels during the rest of the year). Their food consists of animal life (earthworms, white grubs, insect larvae, adult insects, centipedes, millipedes and spiders) and plant life (plant shoots and seeds of oats, corn, and grass). Moles can dig deep tunnels at rates of 12 to 15 feet per hour and in favorable conditions, 1 foot per minute.

Benefits are derived from moles. They help contribute to the formation of good organic soil. Through their subsurface burrowing they aerate and mix soil. They add organic matter in the form of feces. Moles help by eating destructive insects such as cutworms and Japanese beetle larvae that can cause tremendous damage to lawns and gardens.

Damage from moles can be considered harmful when their burrows disfigure lawns and golf courses. They may also dislodge plants and damage bulbs or roots. Mole damage is often confused with damage done by pocket gophers and meadow voles. These other animals often use mole tunnels and are responsible for plant damage.

Voles (or meadow mice, field mice) are active day and night year round. They do not hibernate. They construct many tunnels in the soil and surface runways. They are prey for

many predators (e.g. coyotes, snakes, hawks, owls, and weasels); however, predators do not normally control vole populations. Voles eat grasses, seeds, tubers, and bulbs and will occasionally eat snails, insects, and animal remains.

Damage caused by voles may be extensive to orchards, forests, and ornamental plants even though their activities result in soil mixing and aeration. Voles may cause girdling of seedling and mature trees. Girdling damage is most likely to occur in fall and winter. Field crops (e.g. alfalfa, clover, grain, potatoes) may be damaged or completely destroyed by voles. Vole runways and burrow systems ruin lawns, golf courses, and ground covers.

Pocket Gophers spend most of their lives underground in a tunnel system they dig themselves. It's shoulders and forearms are broad, thick, and muscular which are ideal for digging. Fur-lined cheek pouches on either side of the mouth are used for carrying food to storage chambers. They are active year round and use a wide variety of plants for food, including both above and below ground parts of forbs, grasses, shrubs, and trees.

Benefits can be seen from pocket gophers in many ways. Unfortunately the positive effects are not as visible as the mounds of soil in a hayfield, pasture, lawn, or golf course. It is estimated that an average pocket gopher can move 1 ton of soil to the surface each year. This earth-moving is beneficial because it mixes, aerates, and loosens the soil, all of which benefits plants. This earth-moving allows air and water to reach plant roots which promotes their growth. Their soil-mixing activities make more nutrients available to the upper soil layers. They add organic matter in the form of buried vegetation, unused food, and feces. Dandelions are a favorite food for pocket gophers.

Earthworms are the best living plow in the animal world. A great tunneler whose lips are it's digging tools. Earthworms swallow the soil as they burrow through it, leaving it behind, softer and finer. Through their tunnels air flows to roots of plants. This process helps to keep the soil in an ideal medium for plant root development.

Benefits are numerous from earthworm activity. Earthworms feed on organic matter, converting it to digested matter called "casts." High earthworm populations may be viewed as a visible sign of soil health, because conditions that help them thrive are also good for other soil flora and fauna and plant roots. Earthworms help prevent thatch buildup in lawns by feeding on it.

Nematodes are microscopic animals (eel-like worms). A teaspoon of soil may contain up to 200 nematodes. Farmers are very concerned with parasitic types of nematodes. These animals infest plant roots which provide entry for other fungal or bacterial diseases and reduce yields. Nematodes also feed on decaying organic matter. A few prey on other soil fauna, including other nematodes.

Soil insects also help in altering the soil. **Arthropods**, such as **ants** and some **termite** species alter soil more than other insects by their tunneling. This tunneling mixes the soil and aids in soil aeration. The **Trap-door Spider** and the **Ant Lion** use marvelous skill in making traps for prey. The trap-door spider tunnels six or more inches deep, lines the underground tunnel with earth, mixed with a gluelike substance from its mouth. For it's house, the spider

makes a snug lid or trap door by spinning a thick, round web the size of the opening. This is then covered with a layer of soil. The spider then spins another round web on top of it, repeating the operation until the door is as thick as needs to be. A web is used for hinging the door to the tunnel. Moss is sometimes used to camouflage the door. The spider waits under the door, holding the door ajar with it's abdomen, until unsuspecting prey comes along. When the hapless victim does, the spider seizes it, pops down into the tunnel, and closes the trop door. The ant lion makes a funnel-shaped pit and buries itself almost out of sight at the bottom of it. When an unwary insect falls in, it slides down the sandy sides right into the ant lion's waiting jaws.

These are just a few of the numerous underground dwellers that dig, tunnel, or burrow. Because of their underground activity, the soil is more porous allowing for better water infiltration and air penetration. Explore your yard or garden and identify underground homes and the dwellers who occupy them.

Sources:

Managing Iowa wildlife, moles. Iowa State University Extension, Ames, Iowa. PM-1302b, reprinted September 1991. Prepared for publication by Jim Pease.

Prevention and control of wildlife damage. Institute of Agriculture and Natural Resources, University of Nebraska, 1983. John N. O'Brien, Reno, Nevada 89510.

The Golden Book of Nature Crafts, Hobbies, and Activities for Boys and Girls. Golden Press, New York, 1962. Written by John R. Saunders, Chairman, Department of Public Instruction, The American Museum of Natural History.

Prepared by Eldon C. Weber & Dr. Gaylan G. Scofield, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. May 1993.

Meeting the Needs

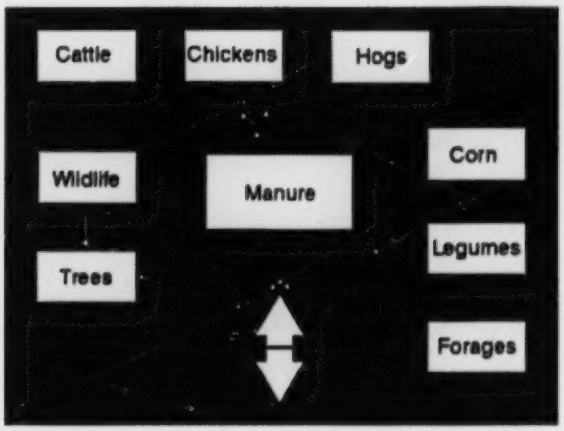
How do plants meet the needs of animals and how does soil fit into the nutrient cycle in this illustration?

In this illustration, the nitrogen fixing plants (alfalfa, clover, and trees) pull nitrogen from the air through animal life, (microbes) that live in the root nodules and convert it into plant food for the crops. The roots of the trees serve as a buffer in taking up excess nutrients and chemicals that might otherwise reach the stream or groundwater. Trees help reduce pollution (sedimentation or underground nutrients that get into the stream or groundwater). Hogs and chickens benefit from eating the high energy food and they return their wastes to the soil providing microorganisms food for their processing back into usable plant nutrients. This is an excellent example of plants and animals (above and below ground) in a symbiotic relationship.

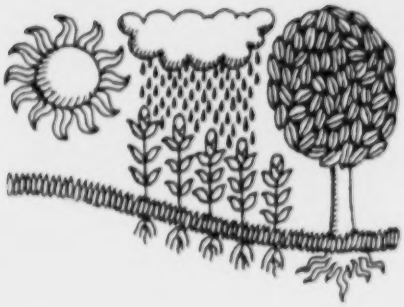
Tom Frantzen, a farmer from Alta Vista, Iowa is experimenting with this concept. He divided 5 acres of sidehill crop land into three 1.7 acre areas. Two rows of hybrid cottonwood poplar trees were planted in each division. For years he has observed a positive relationship between pastured livestock and nearby protective trees. He planted the land between the trees into equal strips of corn, oats, and red clover. The trees and the corn are protected from livestock damage with two strands of electric fence. The intended rotation is corn (to be hogged down in the fall), oats (harvested for grain and straw) and red clover underseeded with oats. Sows farrow on the red clover in June. During August, after the adjacent oat strip is harvested, sows farrow on the two clover strips (this year's seeding and last year's). When the corn is mature, the electric fence is moved to allow the sows and pigs to hog down the crop. Both the water and mineral cycles benefit from this design. The strip effect efficiently harvests the sun's energy. In time, he may plant rows of nut-bearing trees or bushes to add to the economic viability. His current calculations show a gross margin of $170 per acre and he is very excited about the future of this type of plant animal rotational system.

Source: **The Practical Farmer**, Volume 7, Number 3, Fall 1992. Practical Farmers of Iowa Newsletter, Gary Huber, Room 2104, Agronomy Hall, Iowa State University, Ames, Iowa 50011.

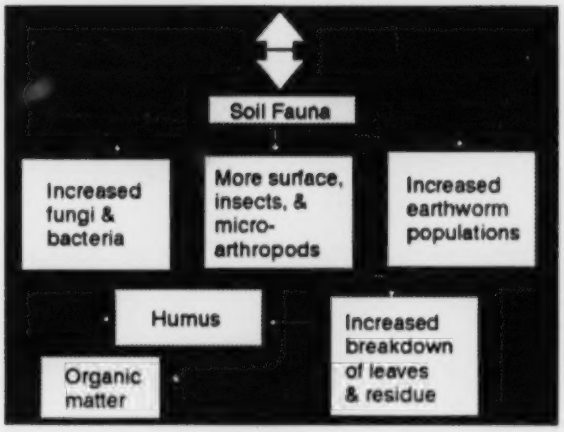
Nature's Soil Factory



The circulation of nutrient elements and compounds in the soil is important to our existence. Animal manures and organic wastes are an important source of both organic matter and plant nutrients.



Soil Line→



This illustrates the nutrient cycle through living organisms and crops above the earth's surface resulting in manure that is further processed by soil organisms resulting in the formation of humus and organic matter. One animals by products becomes another's ones' food.

Prepared by Kenneth L. Wise, Department of Agricultural Education & Studies, Iowa State Univeristy, Ames, Iowa. May 1993.
Edited by Dr. Gaylan G. Scofield & Eldon C. Weber, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. May 1993.

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Interactions Between Plants, Animals, and the Soil

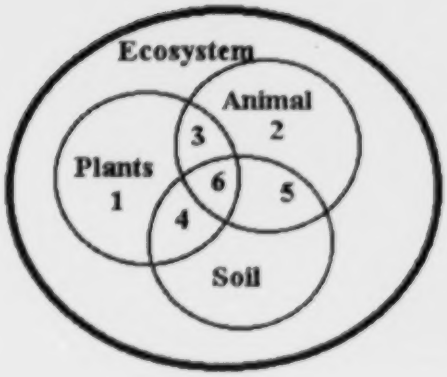
Directions:

Supply the information requested below.

1. Name a plant of your choice.

2. Name an animal of your choice.

3. Explain the relationship between the plant and the animal.



4. Explain the relationship between the plant and the soil.

5. Explain the relationship between the animal and the soil.

6. Describe the relationship between all three (plant, animal & soil).

Prepared by Ken Wise, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. February 1993.
Edited by Dr. Gaylan G. Scofield, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. March 1993.

Example of a Planned Rotational Farming System
Yearly Rotation of Animals and Crops

Stream	Bufferstrip	Corn Shelter Belt	Hog/Chicken Rotation	Nitrogen Fixing Trees & Fryer Chicken Rotation	Beef Cattle Rotation
	Reduces pollutant from entering water Provides wildlife habitat Reduces sedimentation	Provides fall feed for hogs and micro-climate for hogs Reduces wind	Forage alfalfa/ grass/rape Field farrowing Chickens feed on hog by-products, insects that are attracted to the site, and forage	Nitrogen that leaches to the subsoil provides nitrogen to adjacent crops below and excess nitrogen taken up by tree roots	Forage of alfalfa, bluegrass, and clover

How do plants meet the needs of animals and how does soil fit into the nutrient cycle in this illustration?

What examples can you identify locally that fit into the nutrient cycle?

Review INFO-SOIL-5 to learn about what one Iowa farmer is doing.

ACT-SOIL-6

Prepared by Kenneth L. Wise, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. May 1993

Soil Builder

Directions:

Study the illustration **ACT-SOIL-6** (Rotational Farming System) and the description of Iowa farmer Tom Frantzen, **INFO-SOIL-6** (Meeting the Needs) to answer the following questions.

1. How are plants and animals associated to use natural elements to increase soil productivity and farm income?

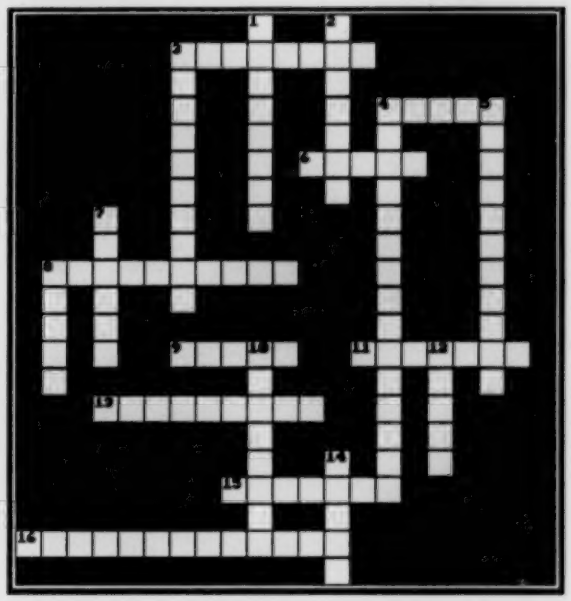
2. Describe other plant and animal combinations that will extract nitrogen from the air, energy from the sun to increase soil productivity, and profits.

3. Would your proposal in question #2 be feasible on a large scale? Why or why not?

Prepared by Eldon C. Weber, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. May 1993.

Vocabulary Challenger Unit I-b

Across:



3. Providing small passageways for air to filter through the soil.
4. Soil animals which chew plant litter into smaller pieces for micro-organisms.
6. Movement of dissolved chemicals through the soil profile.
8. Livestock harvesting standing crops.
9. Animal related soil organisms.
11. Vertical section of soil showing all horizons.
15. Same as 4 across.
16. Plant and animal remains at various stages of decomposition.

Down:

1. Extremely small, single cell organisms.
2. Legume and/or grass feed for livestock.
3. Invertebrate organisms; insects having a segmented external covering and jointed limbs.
4. Invertebrate organisms that can be seen, but more easily identified under a microscope.
5. Same as 4 Across.
7. Nitrogen fixing plant.
8. Decomposed organic matter processed by living soil organisms.
10. _____ cycle involves living organisms converting nutrients to useable forms.
12. A group of simple plants that helps decompose organic matter.
14. Plant related soil organisms.

Prepared by Annette Kiefer, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. May 1993.

Knowledge Builder
Unit I - b

1. Match the following terms with their correct definitions.

___ Aeration	___ Microarthropods
___ Arthropods	___ Mites, Springtails, Beetles, Millipedes
___ Bacteria	___ Nutrient Cycle
___ Forages	___ Organic Matter
___ Fungi	___ Soil Ecosystem
___ Hogged Down	___ Soil Fauna
___ Humus	___ Soil Flora
___ Leach	___ Soil Profile
___ Legume	___ Symbiosis

(a) The living together (dependent on each other) of dissimilar organisms.
(b) A system in which plants and animals inhabit the same location.
(c) Through the recycling (decomposing) of organic matter (plant and animal) living organisms convert nutrients into a form usable for plants.
(d) Extremely small, single cell organisms.
(e) Legume and or grass feed for livestock.
(f) Harvesting a standing crop using livestock.
(g) Movement of dissolved chemicals through the soil profile.
(h) A vertical section of a soil showing all of its horizons.
(i) Providing small passageways for air to filter through the soil.
(j) Invertebrate organisms that can be seen more easily under a microscope.
(k) Decomposed organic matter.
(l) Invertebrate organisms including insects having a segmented external covering and jointed limbs.
(m) A group of simple plants (without chlorophyll) that may be linked together in long filaments called hyphae.
(n) Animal related soil organisms -- bacteria, micro-arthropods, insects, earthworms.
(o) Nitrogen fixing plants (alfalfa, clover, soybeans).
(p) Soil animals which chew plant litter into smaller pieces more suitable for micro-organisms to feed on.
(q) Plant and animal remains and products at various stages of decomposition.
(r) Plant related soil organisms -- fungi, yeasts, molds, smuts, mushrooms.

2. Explain the relationship between the three elements of the ecosystem.

3. Draw and explain the nutrient cycle.

4. Explain why it is important to plan farming systems to resemble natural processes.

A Soil Ecosystem Transparency

Background Information

The soil beneath our feet is full of life. Many animals, such as moles, badgers, and prairie dogs use the soil to find food and shelter. Earthworms and many insects also live in the soil. As these animals burrow and tunnel, they mix the soil, allowing air and water to penetrate beneath the ground's surface. Plant roots stretch down through the soil where they can absorb the air, water, and nutrients needed for growth.

In addition to these plants and animals, billions of microscopic organisms, such as bacteria and algae, inhabit the soil. They, along with fungi, earthworms, and other soil creatures play an important role in the decomposition of organic material. Decomposers help break down dead plant and animal tissue. Nutrients are returned to the soil, where they become available once again to plants.

The next time you stand on the soil, think about the billions of organisms at work beneath you. They are part of a cycle that returns valuable nutrients to the soil. Without these unseen creatures, the plants we depend on for food could not grow, and the life-sustaining cycle on earth would be broken.

About the Transparency

The transparency illustrates a cross-section of hypothetical soil. The top portion of the circular enlargement is about 50X normal size; the center, about 150X; and the bottom about 300X.

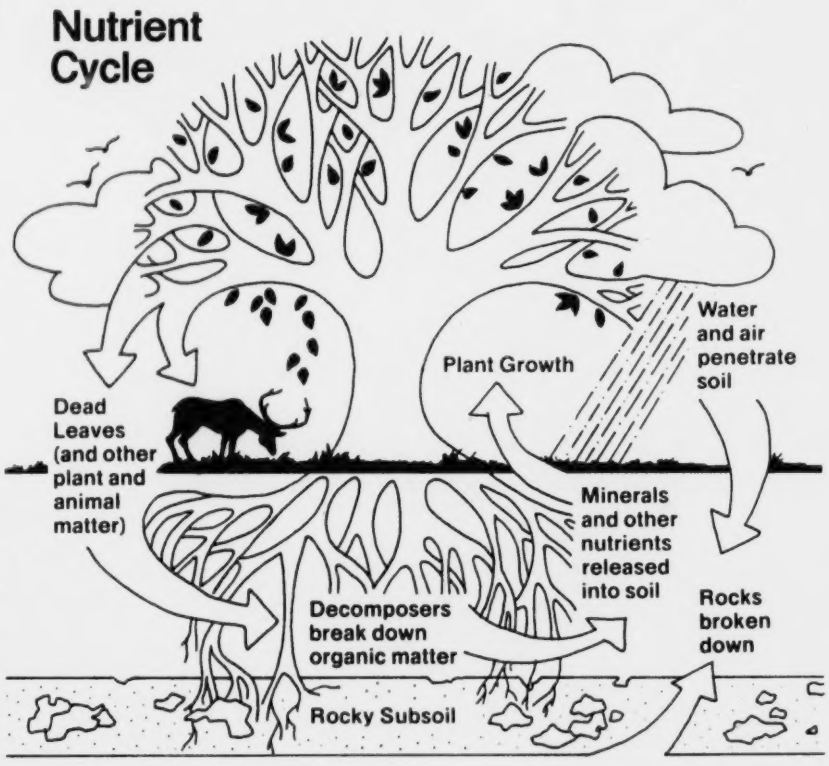
Transparency Use: Write on it with a grease marker. Remove markings with a dry towel. Permanent-ink and water-soluble transparency marker writing cannot be removed without damage to the emulsion.

Activities

★ Use the transparency to introduce the topic of soil.
- What evidence of plant life do you see in this soil profile? (dandelion, grass, leaves, acorn, algae)
- What animals live here? (earthworm, snail, centipede, spider, cricket, daddy-longlegs, shrew, grub, ants, nematode, bacteria)
- What role do these plants and animals play in the ecosystem? How do they use the soil? How do they contribute to the nutrient cycle? Can you see different soil layers? Do some plants extend their roots into the subsoil layer?

★ Collect soil samples from different areas. Working in groups, have your students examine the soil samples using a white tray or sheet of paper, a bright light, forceps, and a magnifier. What different plants and animals can they find? Can they identify them using resources from your library? Find out what role these plants and animals play in the soil ecosystem.

★ Create a soil mural by projecting the transparency onto a large sheet of white paper, using an overhead projector. Trace the image and add other plants and animals that live in the soil.


Nutrient Cycle
Water and air penetrate soil
Plant Growth
Dead Leaves (and other plant and animal matter)
Minerals and other nutrients released into soil
Rocks broken down
Decomposers break down organic matter
Rocky Subsoil

Provided by USDA Soil Conservation Service.

January 1989

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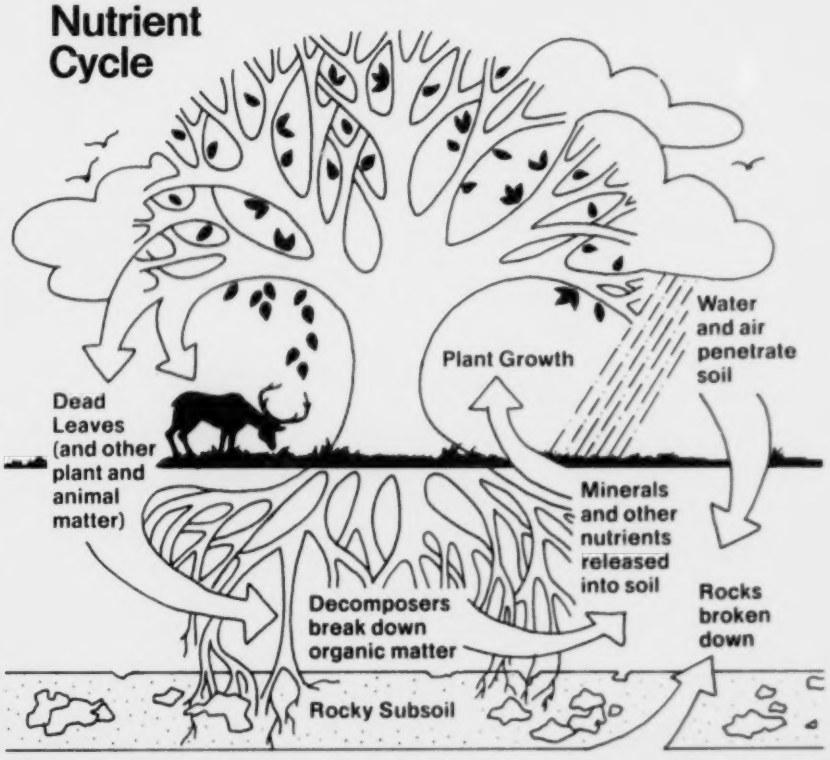
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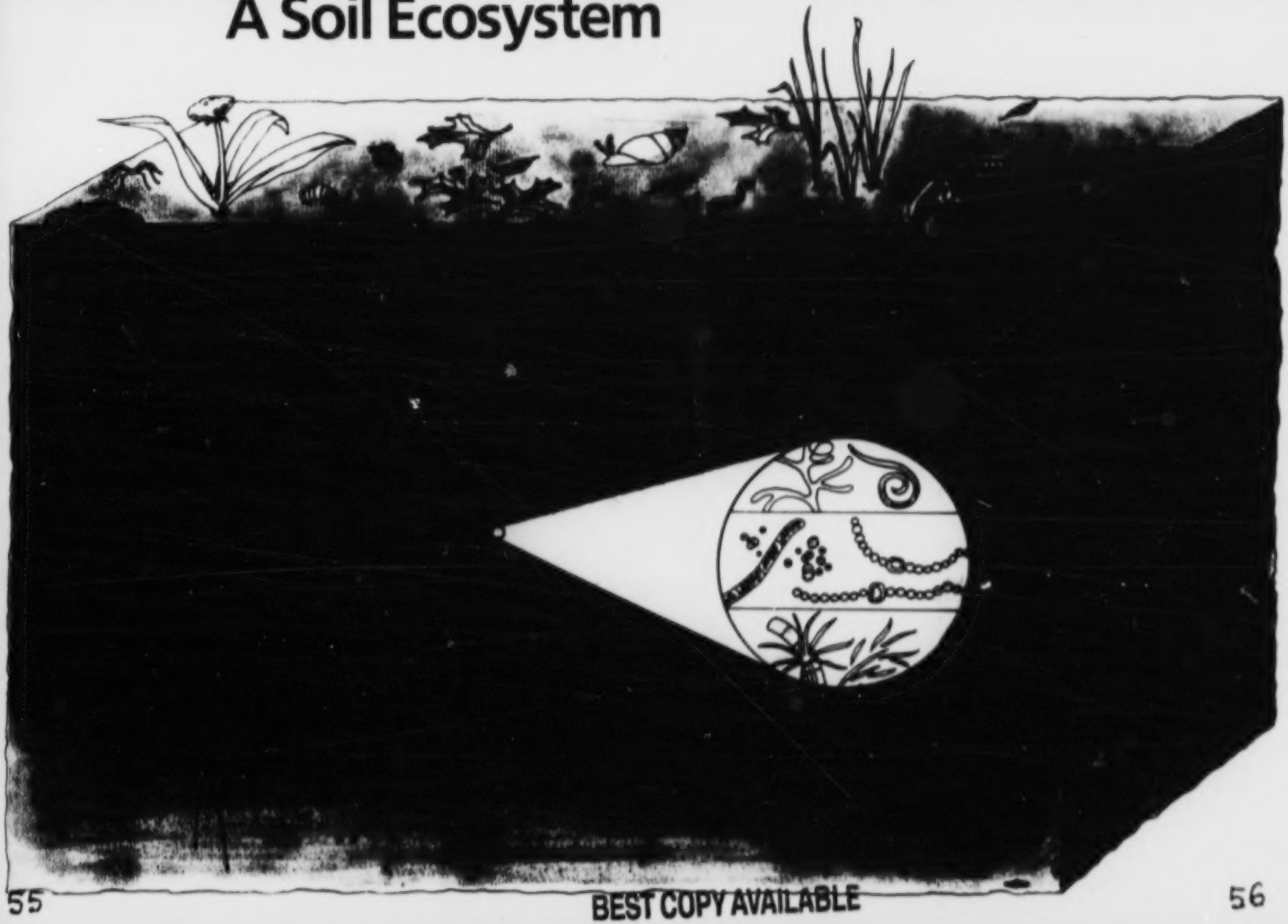
A Soil Ecosystem



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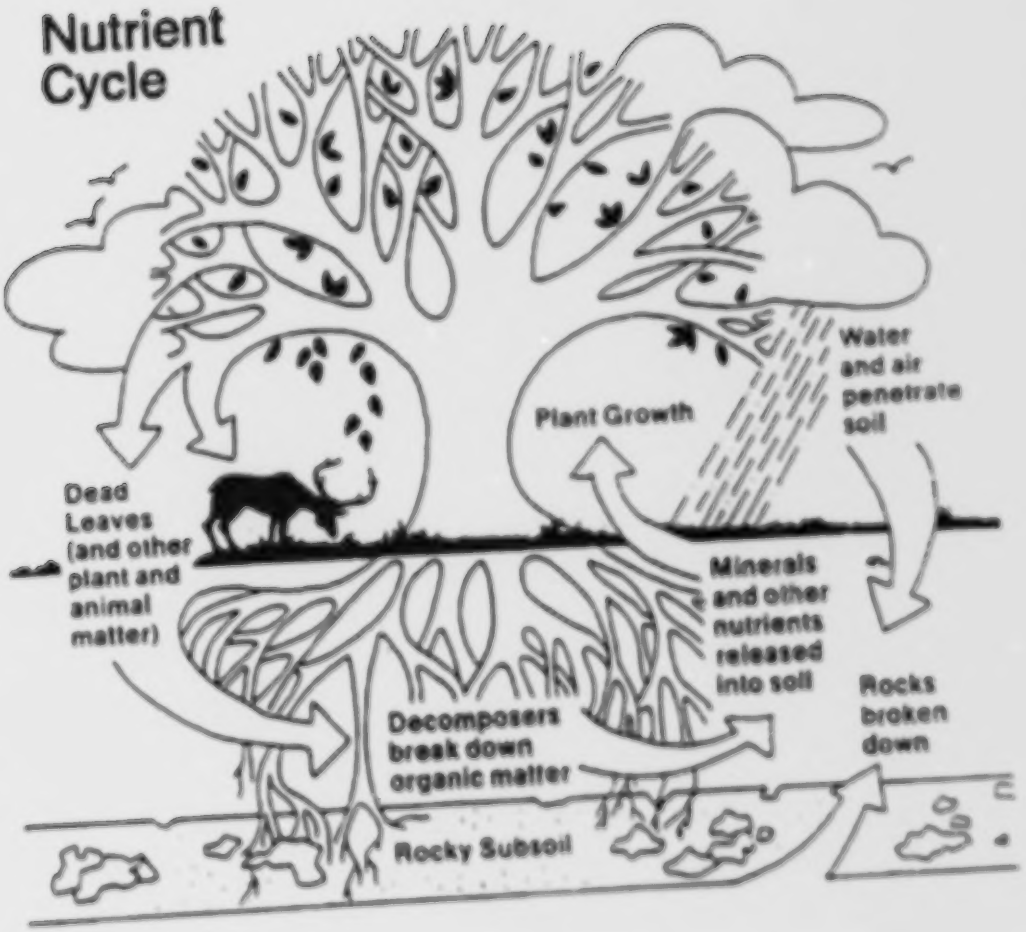
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Rocky Subsoil

A Soil Profile Transparency

Background Information

A soil profile is a slice of earth several feet deep. It shows layers of soil — some less than an inch thick, some over 2 feet thick.

By studying soil profiles, scientists learn about the soil, its characteristics, and how to use and protect it.

Sand, silt, and clay are the various sized particles that make up soils. The texture of a soil is determined by the relative amounts of these particles in the soil. For example, a sandy clay soil may contain about 50 percent clay, 45 percent sand, and 5 percent silt. Loam soils contain about equal amounts of all three.

Some soils were formed by the breaking down and weathering of rock. Others were formed from materials transported and deposited by water, wind, or glaciers. Deep soil layers and rock change very slowly.

It takes 100 to 600 years, or more, to form an inch of topsoil. Wind and water erosion can remove that much topsoil in a single year. When a soil erodes excessively, the exposed subsoil is more difficult to cultivate and less productive for plant growth.

About the Transparency

Most soil profiles have a surface layer of organic material and two or three layers of mineral materials. These are the horizons of a typical soil profile.

If present as organic material, the 0 horizon at the top is usually less than an inch thick. The dead plant and animal materials decompose into nutrients that enrich the soils.

Topsoil, the A horizon, is the upper soil layer. Plant roots, bacteria, fungi, and small animals are abundant. Plants thrive in it. It has more organic matter and is darker than the subsoil.

Subsoil, the B horizon, is the middle soil layer. It has fewer organisms and less topsoil. Plants don't grow as well in it. If subsoils are clayey, they usually are harder when dry and stickier when wet than the surrounding soil layers.

The C horizon is the lowest layer. It is less altered and weathered than the layers above and has less living matter. It may be called the parent material. It gets this name because it is the weathered rock and partly weathered soil from which the soil layers above were formed.

Transparency Use: Write on it with a grease marker. Remove markings with a dry towel. Permanent-ink and water-soluble transparency marker writing cannot be removed without damage to the emulsion.

Activities

★Use the transparency to introduce the topic of a soil profile.

...What differences are there in the horizons? (depth, color, plant growth, soil particle or rock size)

...Why is the particle size important to plant growth and the water-holding capacity of soil? (more total surface area on small particles, better aeration/water flow through mixed soil sizes)

...What results if plant cover is absent? (soil erosion/lost fertility)

★Locate different soil profiles in streambanks, roadside cuts, and building-site excavations. Have students point out color, texture, and appearance changes in the horizon, measure horizon depths, sketch the profiles studied.

★Fill a fruit jar 2/3 full of water, add soil to nearly fill it; shake vigorously. Let soil fully settle. Have students hold paper beside the jar, draw the different layers, and label each as clay, silt, sand, or rocks.

★Collect samples of sand, silt, and clay from various sites. Have students examine and describe each sample. Identify soil textures (most examples will be mixtures).

★Show how soil is created.

...By abrasion: Rub together limestone, sandstone, brick, or concrete.

...By heating: Fully heat limestone and drop it in ice water; it should crack or break.

...By freezing: Freeze water in a glass jar; what happens to the jar? Water trapped in rock freezes and rocks break into smaller and smaller pieces.

Provided by USDA Soil Conservation Service

March 1989

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What results if plant cover is absent? (soil erosion/lost fertility)

★Locate different soil profiles in streambanks, roadside cuts, and building-site excavations. Have students point out color, texture, and appearance changes in the horizon, measure horizon depths, sketch the profiles studied.

★Fill a fruit jar 2/3 full of water, add soil to nearly fill it; shake vigorously. Let soil fully settle. Have students hold paper beside the jar, draw the different layers, and label each as clay, silt, sand, or rocks.

★Collect samples of sand, silt, and clay from various sites. Have students examine and describe each sample. Identify soil textures (most examples will be mixtures).

★Show how soil is created.

By abrasion: Rub together limestone, sandstone, brick, or concrete.

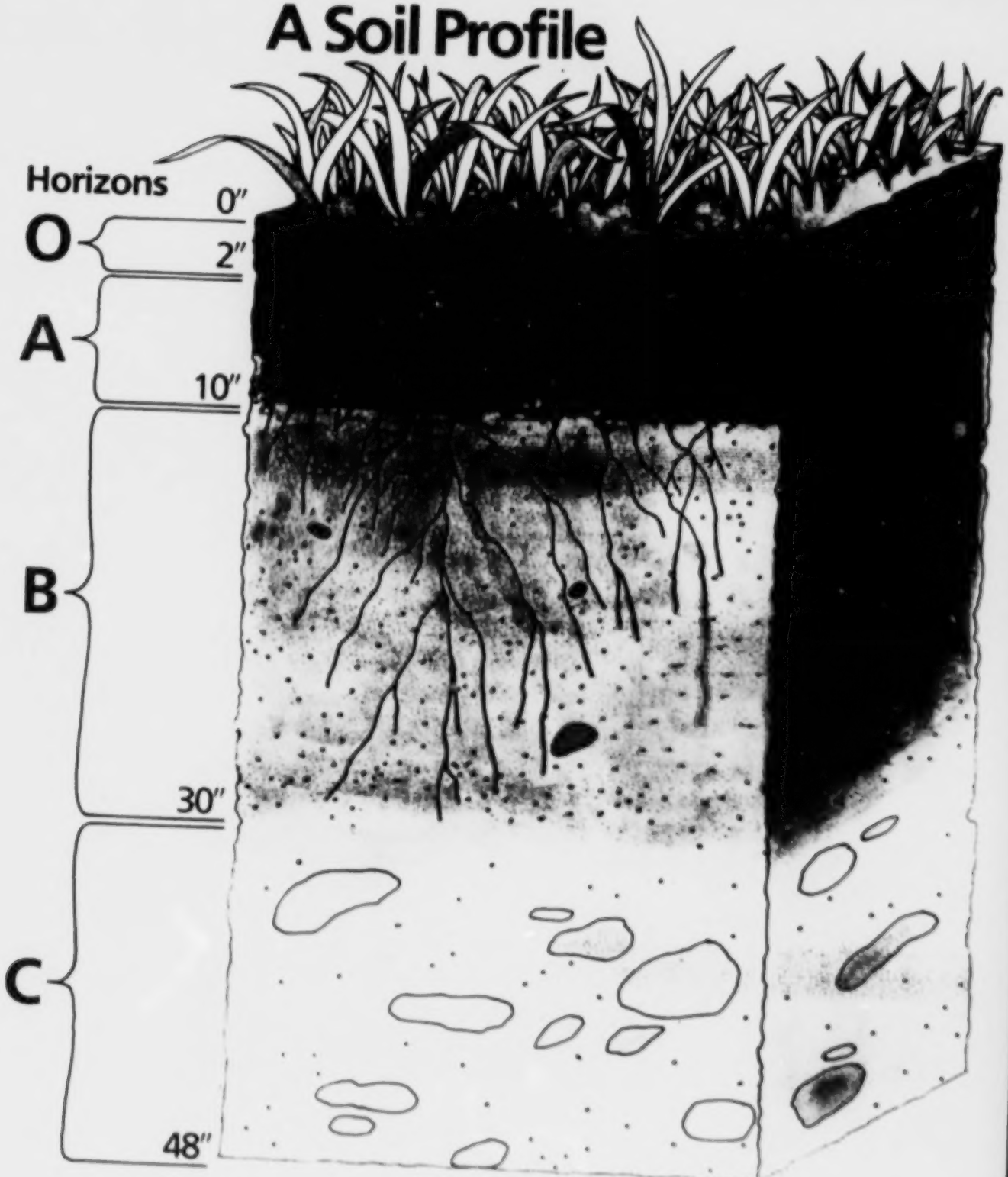
By heating: Fully heat limestone and drop it in ice water; it should crack or break.

By freezing: Freeze water in a glass jar; what happens to the jar? Water trapped in rock freezes and rocks break into smaller and smaller pieces.

Provided by USDA Soil Conservation Service

March 1989

A Soil Profile



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Summary

- ✓ There are many benefits to having active life under the soil surface
- ✓ Soil is full of life (plants, animals, and microscopic organisms)
- ✓ Soil life plays an important role
  - ☛ decomposing organic matter
  - ☛ increasing aeration
  - ☛ increasing water infiltration
  - ☛ increasing soil fertility

Unit I - c
Discovering the Impact of Tillage & Nutrient Management Systems on Soil Health

Introduction

Farmers, gardeners, and horticulturists need to be good land managers, which results in long-term soil and water protection and profitable enterprises. The type of farming systems or tillage used has a direct bearing on soil characteristics and plant growth.

Objective

Participants will discover the impact of tillage and nutrient management systems on soil health.

Competencies

1. Analyze the environmental impact that management practices may have on soil.
2. Explain the impact agriculture has on natural resources and the environment.
3. Identify contemporary natural resources issues/concerns relating to growing food and feed.
4. Compare cropping and livestock systems for best long-term results.

Materials

1. News print and markers.

Information

INFO-SOIL-8 Vocabulary Builder

Activity

ACT-SOIL-10 Vocabulary Challenger
ACT-SOIL-11 Knowledge Builder

Visual Masters

VM-SOIL-6 Living Soil Definition (graphic)
VM-SOIL-7 Living Soil Definition (overlay #1)
VM-SOIL-8 Living Soil Definition (overlay #2)
VM-SOIL-9 Living Soil Definition
VM-SOIL-10 Summary Unit I - c

Teaching Procedure

1. As an **Interest Approach**, ask participants to write one or two sentences explaining their definition of the "Living Soil" on newsprint. Have each participant share their definition with the others. Discuss common items found in all definitions.

2. Use **INFO-SOIL-8** (Vocabulary Builder) to review key terms for this unit.

3. Use **VM-SOIL-6, 7, 8, & 9** (Living Soil Definition) to define "Living Soil". **VM-SOIL-6** displays several key elements of the living soil. Ask participants to identify elements found in the picture.

   Elements
   plants, insects, earthworms, animals, microbes

4. Overlay **VM-SOIL-7** on top of **VM-SOIL-6** and discuss with participants the three factors affecting soil health. Ask "What does soil health mean to you?" Ask "Which soil would be the healthiest, one that crusts over after a rain or one that does not? Why?" The healthiest soil will grow the best crops for an indefinite period of time. Possible answers could include:

   Physical factors
   soil pore size, water holding capacity, water infiltration rate, permeability, structure, aggregate size, organic matter, texture

   Chemical factors
   soil fertility, plant nutrients, organic chemicals, soil pH

   Biological factors (living organisms)
   plant roots, bacteria, fungi, insects, earthworms, animals

5. Overlay **VM-SOIL-8** on top of **VM-SOIL-7** and discuss human impact based on the three management areas listed. Ask "How does the management of soil, insects, and nutrients affect the physical, chemical, and biological factors?" Ask "Compare the soil physical factors of a field that has been plowed, disked, and harrowed year after year using continuous corn to one that has had reduced tillage or no-tillage before planting for several years and has been rotated with corn and legumes. What differences can be observed?" Possible answers could include:

   Soil Management
   Soil that has had years of several tillage operations (continuous corn) per year compared to reduced tillage or no-till (rotated crops) will have less organic matter at the surface, a finer soil that will tend to crust over after a rain and will have less pore space for water and air movement. Soil management practices include different tillage systems, erosion control, residue management, and various conservation practices.

Insect Management
Continuous cropping requires more chemicals to control insects because the natural insect cycles are not broken up with different crops. Insect management practices include integrated pest management, crop rotations, and chemical management.

Plant management
Continuous cropping will not have the natural, physical, chemical, or biological make-up to support the best plant growth. Plant management practices include cropping systems and nutrient management.

6. Use **VM-SOIL-9** to summarize the "Living Soil" definition. Have participants explain why it is a "food factory."

   Living Soil: "Food factory" containing the proper mixture of living organisms, mineral and organic matter, air, and water is like a manufacturing plant in recycling nutrients and in developing soil.

7. With help from participants, develop a list of management practices that help maintain or improve the living soil. Develop a list of things which harm the living soil. Refer to concepts discussed with **VM-SOIL-6, 7, 8, & 9**.

8. Discuss how each management practice identified in **#5** influences the living soil. Ask participants to identify alternatives or changes that would reduce harmful effects.

9. Use **ACT-SOIL-10** (Vocabulary Challenger) to review terms associated with this unit.

   Across: 2. soil structure 5. aggregate 6. chemical factors

   Down: 1. biological factors 3. permability 4. physical factors 7. texture

10. Use **VM-SOIL-10** (Summary Unit I-c) to relate the following conclusions. The soil contains many living things. There are three factors that affect soil health. Soil health is also dependent on human impact. The "Living Soil" is a "food factory".

11. Use **ACT-SOIL-11** (Knowledge Builder) for Unit I-c summary or evaluation.

    Q1. Match the following terms with their correct definitions.

    A1.
    g aggregate
    b biological factors
    f chemical factors
    a permeability
    d physical factors
    c soil structure
    e texture

    Q2. Define soil management.

    A2. Practices used to conserve and develop soil.

Q3. List the three factors affecting soil health.

A3. Physical, Chemical, Biological.

Q4. List three insect management tools.

A4. Biological, mechanical or physical, chemical.

Q5. The living soil contains many different things. List three of them.

A5. Living organisms, minerals, air, water, organic matter.

Q6. Draw a cross section of soil showing a soil ecosystem.

A6. Evaluate on an individual basis.

Vocabulary Builder
Unit I - c

Aggregate - Lumps of various sizes formed by soil particles sticking together.

Biological Factors - Living organisms.

Chemical Factors - Soil fertility, plant nutrients, soil pH.

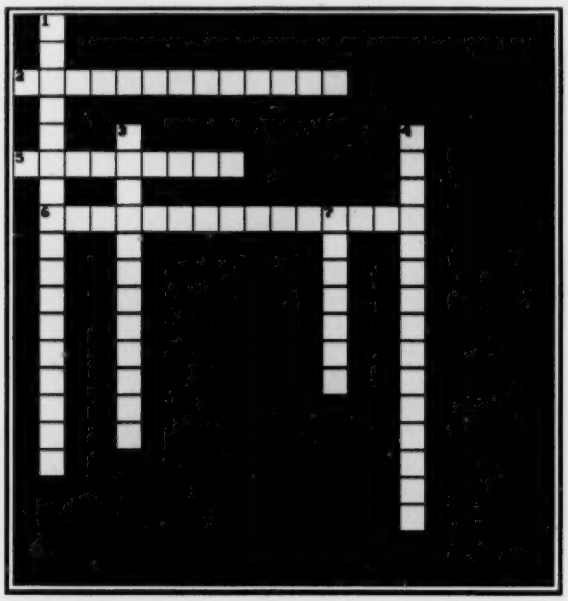
Permeability - The ease with which something can pass through the soil.

Physical Factors - Soil pore size, water holding capacity, water infiltration rate, soil structure, texture, aggregate size, permeability.

Soil Structure - The way that soil particles are arranged together.

Texture - The relative portion of the various sizes of particles (sand, silt, clay).

Vocabulary Challenger Unit I-c



Across:

2. The way that soil particles are arranged together.

5. Lumps of various sizes formed by soil particles sticking together.

6. Soil fertility, plant nutrients, soil pH.

Down:

1. Living organisms.

3. The ease with which something can pass through the soil.

4. Soil pore size, water holding capacity, water infiltration rate, soil structure, texture, aggregate size, permeability.

7. The relative portion of the various sizes of particles (sand, silt, clay).

Prepared by Annette Kiefer, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. May 1993.

Knowledge Builder
Unit I - c

1. Match the following terms with their correct definitions.

___ Aggregate
___ Biological Factors
___ Chemical Factors
___ Permeability
___ Physical Factors
___ Soil Structure
___ Texture

(a) Lumps of various sizes formed by soil particles sticking together.
(b) Living organisms.
(c) Soil fertility, plant nutrients, soil pH.
(d) The ease with which something can pass through the soil.
(e) Soil pore size, water holding capacity, water infiltration rate, soil structure, texture, aggregate size, permeability.
(f) The way that soil particles are arranged together.
(h) The relative portion of the various sizes of particles (sand, silt, clay).

2. Define soil management.

3. List the three factors affecting soil health.

4. List three insect management tools.

5. The living soil contains many different things. List three of them.

6. Draw a cross section of soil showing a soil ecosystem.

Soil Health

Factors

C H E M I C A L

P H Y S I C A L

BIOLOGICAL

Prepared by Dr. Gaylan G. Scofield, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. February 1993

VM-SOIL-6

Human Impact

Management

PLANT

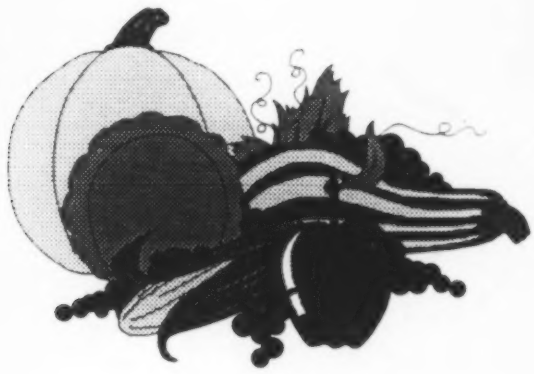
INSECT

SOIL

Prepared by Dr. Gaylan G. Scofield, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. February 1993

Living Soil

"Food factory" containing the proper mixture of living organisms, mineral and organic matter, air, and water is like a manufacturing plant in recycling nutrients and in developing soil.



Summary

√ Soil contains many living things

√ 3 factors affect soil health

- ☞ Biological
- ☞ Chemical
- ☞ Physical

√ Soil health is dependent on human impact

√ "Living soil" is a "food factory"

Unit I - d
Discovering the Role of Earthworms in Maintaining Good Soil Health

Introduction

Earthworms are not much to look at, yet their ecological significance is both great and far-reaching. Earthworms are simple animals. The earthworm and its way of life are very important to many living soil organisms.

Objective

Participants will become familiar with the importance of earthworms in maintaining soil health.

Competencies

1. Explain the significance of earthworms in relationship to soil health.
2. Explain limiting factors of successful plant/crop growth.
3. Analyze and interpret charts, graphs, or other information to make sound management decisions.
4. Organize thoughts and clearly express point of view.
5. Apply/use scientific methods/analysis.
6. Follow directions correctly.
7. Maintain clean and orderly work area.
8. Work effectively with others as shown/demonstrated by instructor.

Materials

1. Light colored subsoil, dark colored topsoil, potting soil, grass sod, earthworm castings.
2. Several containers of various sizes:
   - small glass containers (1 quart jars).
   - 3 containers suitable for growing bean plants.
   - 2' x 4' x 2' container with lid and drainage holes.
   - large aquarium with layer of small stones.
   - 12" x 12" x 8" container.
   - 2 glasses containing water.
3. Opaque paper, newspaper, duct tape, heavy string, plywood square 12" x 12".
4. Earthworms.
5. Grass clippings, vegetable or fruit scraps, or other earthworm "food".
6. 3 kinds of crop residue and organic debris.
7. Bean seed.
8. 3' of 6" pvc plastic pipe cut into 6" lengths
9. 2 flashlights (clear lens and red or green lens).
10. Window screening, burlap.

Information

INFO-SOIL-9 Vocabulary Builder
INFO-SOIL-10 The Living Soil

Activities

ACT-SOIL-12 Earthworm Body Parts
ACT-SOIL-13 The Living Soil Concepts
ACT-SOIL-14 Vocabulary Challenger
ACT-SOIL-15 Knowledge Builder

Visual Masters

VM-SOIL-11 Earthworm Body Parts
VM-SOIL-12 Summary Unit I - d
VM-SOIL-13 Summary Unit I - d

Labs

LAB-SOIL-1 Earthworms and Soil Mixing
LAB-SOIL-2 Earthworms and Plants
LAB-SOIL-3 Composting with Earthworms
LAB-SOIL-4 Earthworm Tolerance to Chemicals
LAB-SOIL-5 Earthworm Burrows
LAB-SOIL-6 Earthworm and Soil Structure
LAB-SOIL-7 Earthworms and Residue Utilization
LAB-SOIL-8 Composting with a Wiggle & **LAB-INFO-1** Bottle Basics Preparation Sheet
LAB-SOIL-9 Earthworm Farm
LAB-SOIL-10 Earthworm Intelligence
LAB-SOIL-11 Earthworm Food Preference
LAB-SOIL-12 Earthworm Sensitivity

Teaching Procedure

1. As an **Interest Approach**, ask participants to write a paragraph about earthworms explaining their importance. Have each participant share their paragraph. Develop a list of known facts/information about the earthworm.

2. Use **VM-SOIL-11** (Earthworm Body Parts) to discuss earthworm body parts. Discuss how the body parts are similar/different to other animals. Have participants record the information on **ACT-SOIL-12**. Ask participants to research information on earthworms.

A. Body wall	E. Upper lip	I. Egg sac
B. Blood vessels	F. Mouth	J. Crop
C. Intestine	G. Throat	K. Gizzard
D. Brain	H. Hearts	

3. Use **INFO-SOIL-9** (Vocabulary Builder) to review key terms with participants.

4. Assign reading from **INFO-SOIL-10** (The Living Soil). Have participants complete activity sheet **ACT-SOIL-13** (Living Soil Concepts). Discuss the answers and/or use for evaluation.

   Q1. Define soil.

   A1. Soil is a collection of natural bodies mineral and organic matter capable of supporting growth of plants.

   Q2. Name the two components of soil quality.

   A2. The two components of soil quality are soil tilth and soil health.

   Q3. Describe how the two components of soil quality can be improved over a period of time.

   A3. Soil tilth and soil health can be improved over a period of time through the use of reduced tillage, good drainage programs, favorable fertility, use of cover crops, animal manure or green manure, crop rotations utilizing forages or grasses, and reduced traffic over fields.

   Q4. Discuss the dual function of nature's composting of crop residue.

   A4. Nature's composting provides nutrients for plant growth and improves the structure of the soil. A soil that contains good organic matter soaks up rain like a sponge and regulates the supply to plants. Soil with little or no organic matter resists water penetration thus leading to destructive compaction, erosion, and flooding. A loose, healthy soil assists in the spreading of air into the soil and also helps in the exchange of nutrients and moisture.

   Q5. Tillage may be considered as a means of temporary soil conditioning. Describe conditions when tillage harms the soil.

   A5. Tillage should only be performed when the soil is evenly moist. Tilling hard, dry soil breaks down the structure. Wet soil is heavy and easily compacted. Repeated tillage destroys a friable structure and minimizes aeration.

   Q6. Discuss the advantages of reduced tillage or no-till.

   A6. Advantages include fuel savings, less costly trips across the field, less machinery, labor saving, soil saving; improved soil structure, water infiltration, air infiltration, and root movement; increased earthworm activity, organic matter content, and biological activity.

Q7. Compare/contrast the earthworm's internal structure to other agricultural animals.

A7. The earthworm's internal structure is similar to the chicken's. The earthworm has a mouth but not teeth. Soil and food swallowed are pushed through the esophagus to a chamber, or sac, called the crop. The crop stores food for a short time. Then, the food passes into the gizzard. The gizzard has strong muscles which grind the food and are aided by tiny stones from the soil. Earthworms have five hearts.

Q8. Describe ideal earthworm conditions.

A8. Earthworms prefer well-drained (but moist), fertile soils that contain plenty of organic matter. They prefer a neutral pH or nearly neutral soils.

3. Review **LABS-SOIL-1 to 12** and assign individually or in small groups. Have participants explain the lab experiment and their findings orally to the class. Discuss their findings and the conclusions.

Conclusions Note: Results may vary due to local conditions.

LAB-SOIL-1 Earthworms and Soil Mixing

After several days, you will see considerable mixing of light and dark soil. This clearly demonstrates the ability of earthworms to mix soils and to create channels (burrows) in the soil. All these effects in the soil produce better infiltration of water. This helps proper drainage of the soil and reduces erosion. Also the earthworm casts (waste products) promotes better structure which helps to reduce soil compaction. Earthworm activity mixes surface residue into the soil.

LAB-SOIL-2 Earthworms and Plants

Earthworms are big eaters. Earthworm castings are rich in minerals, especially nitrates, along with sulfur, calcium, potassium, phosphorus, and magnesium. Decay of plant and animal tissue does not happen by itself. Decay is caused by many small forms of life such as bacteria, mites, springtails, beetles, millipedes, and earthworms. Their feeding releases the minerals in a form the plants can use. The plant in the container with earthworms should show a difference in size. It probably will be taller, bushier, and healthier-looking. By feeding and burrowing, the earthworm goes about its own life; but its way of life is very important to the health of green plants and that means earthworms are important to all of us.

LAB-SOIL-3 Composting with Earthworms

Compost improves soil structure by holding soil together and giving it a crumbly texture. The addition of compost increases the soil's porosity so that plant roots can easily penetrate it. Compost also helps hold moisture and inorganic minerals. Compost

attracts earthworms and provides them with food. The tunnels that earthworms create aerate the soil and improve drainage. Earthworm burrowing brings up minerals from the subsoil and makes them available to plants. Earthworms are very efficient recyclers of organic matter.

LAB-SOIL-4 Earthworm Tolerance to Chemicals

The widespread use of pesticides has raised questions about toxicity to soil organisms, especially earthworms. Earthworms are beneficial in increasing the porosity of the soil. Correct use and proper application of pesticides can reduce the toxic effect on earthworms and other soil organisms.

LAB-SOIL-5 Earthworm Burrows

Earthworms are active in creating burrows in the soil. These burrows allow surface water to be absorbed by the soil, thus reducing surface runoff. Plant roots utilize the burrows for their roots. Earthworms help mix the soil with organic matter, giving it better structure.

LAB-SOIL-6 Earthworm and Soil Structure

The piece of sod will break up much faster than the casting. Earthworm castings in soil may help reduce erosion. These castings make fertilizer which is rich in nitrate, phosphate, and potash. It has been estimated that the 2 to 3 million earthworms living on one acre can produce from 12 to 18 tons of castings in 45 days.

LAB-SOIL-7 Earthworms and Residue Utilization

Earthworms are the earth's living plows. Through their tunneling, earthworms loosen the soil and so change the environment of all other soil-inhabiting organisms, including plant roots. Earthworm holes and decaying roots develop many large pores throughout the soil profile. These pores help improve water infiltration. Earthworms utilize crop residue as a food source. Some of this residue is consumed on the surface during feeding at night. Other pieces of residue is used to help form middens over their burrow openings. The middens act as small roofs, protecting the burrow from rain. Some scientists believe the middens help control the humidity level in the burrow. Still other pieces of residue are pulled into the burrow and becomes mixed with the soil.

LAB-SOIL-8 Composting with a Wiggle

Earthworms help nature in decomposition and recycling. Earthworms utilize organic matter as a food source. Some of the organic matter is mixed with the soil, helping to improve it.

LAB-SOIL-9 Earthworm Farm

After a month or two it is time to check for eggs. Dump out all the bedding and remove the large earthworms, which you can put into a new culture. The old bedding with the cocoons and the tiny white baby earthworms can be put back into the original box where they now will have room to grow and develop. Another method of removing the large earthworms from the box is to stop feeding them for a few weeks and then place some food in one corner of the box. You can probably scoop up most of the large earthworms in the evening when they surface to feed. To secure your own earthworms, use a garden fork rather than a spade or shovel, which may injure too many earthworms.

LAB-SOIL-10 Earthworm Intelligence

After several trials and errors, the earthworm will learn to select the right turn to escape into the soil.

LAB-SOIL-11 Earthworm Food Preference

Earthworms do have a preference for the food they consume. Most earthworms will eat cabbage leaves if no other food is available, but they will probably prefer the celery leaves if both are offered. If they have a choice of all three food items, they seem to prefer carrot tops. Try to feed them bits of fruit and different vegetable matter and see in what order they consume the food. Earthworms prefer food that is rotted. They also like oatmeal, cornmeal, chick starter or laying mash, and even coffee grounds.

LAB-SOIL-12 Earthworm Sensitivity

The light-sensitive cells in the front and tail ends of the earthworm help it sense light. The outer covering of the earthworm is sensitive to vibrations or touching. The earthworm will move away from the clear white light. The colors red and green are not brightly visible to earthworms and many animals. Earthworms are very sensitive to vibrations and touch.

4. Summarize the concepts presented in the instructional unit with **VM-SOIL-12 & 13**.

VM-SOIL-12

Soil is a complex network of living things dependent on each other for survival.

Correct land management protects and enhances our soil while maintaining a suitable environment for life (microbes and earthworms) that live there.

Soil is earth's most valuable resource, which directly or indirectly provides food we and other animals need to stay alive and healthy.

Earthworms are an indicator of good soil quality.

Proper soil, insect, and plant management practices are needed to maintain ample earthworm numbers.

People do not fully realize that soil organisms help to make soil productive.

5. Have participants construct posters describing "The Living Soil" or divide participants into small groups and have each prepare an exhibit for the classroom, a fair, or a local store window to promote "The Living Soil." Have participants explain the concepts which their posters show. Posters may be used for evaluation.

6. Use **ACT-SOIL-14** (Vocabulary Challenger) to review key terms in the unit.

Across: 1. friable 3. earthworms 5. actinomycetes 8. composting 11. ecological 13. setae 14. midden 16. nematodes 17. nightcrawler

Down: 2. burrow 4. no-till 6. castings 7. cocoons 9. gizzard 10. neutral pH 12. green manure 15. redworms

7. Use **ACT-SOIL-15** (Knowledge Builder) to summarize or evaluate Unit I-d.

Q1. Match the following terms with their correct definitions.

A1.

c	Actinomycetes	k	Green Manure
n	Burrows	i	Midden
h	Castings	d	Nematode
j	Cocoons	e	Neutral pH
g	Composting	a	Nightcrawler
p	Earthworm	f	No-till
l	Ecological	b	Reduced Tillage
m	Friable	j	Reduced Traffic
r	Gizzard	q	Setae

Q2. Why are earthworms an indicator of good soil health?

A2. In feeding, the earthworm breaks down plant and animal wastes. Earthworms help release minerals that plants need. Although earthworms help improve soil, they cannot change really bad soil. Earthworms will not live in a poor quality soil.

Q3. Why is it important to leave crop or plant residue on the soil surface?

A3. The crop or plant residue helps nature to protect the living soil from erosion and evaporation. Weed seeds are prevented from germinating and the soil is protected from the impact of raindrops and winter frost penetration. Microorganisms as well

as earthworms remain active in the surface layer that is protected from drying out and from temperature extremes.

Q4. How do humans impact the living soil?

A4. Mismanaging the soil allows for the breakdown of soil structure and for soil erosion to occur which in turn destroys the habitat of the soil organisms (natures recyclers).

Q5. Compare/contrast the body parts of an earthworm to other agricultural animals..

A5. The earthworm has a mouth but no teeth. Soil and food swallowed is pushed through the esophagus to a chamber or sac called the crop by muscles. The crop stores food for a short time; then the food passes into the gizzard. The gizzard has strong muscles which grind the food, aided by tiny stones from the soil which the earthworm has swallowed with its food. Special glands in the intestine secrete juices to digest it. Some of the digested material is absorbed into the bloodstream and distributed to the earthworm's body while the rest is expelled as wastes. This is similar to the chicken.

Q6. Write 1 to 2 paragraphs on your land ethic.

A6. Answers will vary.

Q7. Draw a picture of the living soil.

A7. Answers will vary.

Vocabulary Builder
Unit I - d

Actinomycetes - A group of microorganisms, intermediate between bacteria and fungi which are active in decomposing and responsible for the earthy smell of compost.

Burrow - Earthworm tunnel.

Castings - Waste product from earthworms rich in nitrate, phosphate, and potash.

Cocoons - Contains baby earthworms.

Composting - Biological degradation or breakdown of organic matter by a managed process.

Earthworm - Maybe the most important creature in the history of the world.

Ecological - Relationship between organisms and the environment.

Friable - Readily crumbled soil.

Gizzard - Organ where the earthworm's food is ground.

Green Manure - A crop such as alfalfa normally tilled into the soil which results in the addition of natural nitrogen and organic matter.

Midden - The castings of earthworms which serve as a lid to their burrows.

Nematodes - A group of small worm-like animals which commonly inhabit soils and feed from plant roots and other organisms.

Neutral pH - Neither acid or alkaline (5.5 - 7.0 pH).

Nightcrawler - Large earthworm that burrows vertically.

No-till - Planting without disturbing the soil.

Red Worm/Common Garden Worm - Smaller earthworms which burrow horizontally and eat under the surface of the earth.

Reduced/Minimum Tillage - Tillage which leaves at least 30% of residue coverage on the soil surface before planting.

Reduced Traffic - No-till or ridge till provides opportunities to keep implement wheel tracks in the same location every year allowing for natural soil development in the crop row.

Setae - Small hooks on the earthworms' body used to pull themselves along.

The Living Soil

Introduction

Pick up a handful of soil and notice how it feels and looks. The soil you hold in your hand is a complex mixture of inorganic minerals (mostly clay, silt, and sand), decaying organic matter, water, air, and living organisms. Imagine the soil you hold is the earth's surface. Drop three-fourths of it back on the ground. The amount dropped represents how much of the earth is covered by oceans, rivers, and lakes. The remaining soil represents the land. Drop one-half of the remaining soil from your hand. The amount dropped represents the desert regions, glacial poles, and mountain peaks where many things won't grow. Drop one-tenth of the remaining soil from your hand. The amount dropped represents the land where people live -- cities, towns, houses, schools, roads, and parking lots. The soil left in your hand represents all the soil we have to support life on earth. The earth's thin layer of soil (at most only a meter or two thick and in many cases none at all) provides nutrients for plants which directly or indirectly provide the food we and other animals use to stay alive and healthy.

The world community depends upon the fertility of soil to produce necessary food crops. In areas where natural soil is abundant and fertile or where it is possible to amend the natural soil to increase its fertility, sufficient food crops can be produced. Soil is a collection of natural bodies of the earth's surface containing living matter which is able to support the growth of plants. One must dig a hole to see what soil looks like below the surface because it is not possible to learn much from distance without examining it closely.

A handful of soil may contain more living organisms than there are people in the world. Soil microorganisms cause the decay of plant residues thus releasing carbon dioxide, ammonia, and minerals essential to crop growth. They also release essential mineral elements from the soil making these available for plant use. Soil management practices are needed to encourage work of beneficial soil microorganisms and to help crops suffering from the effects of detrimental soil organisms.

Quality Soil

A productive soil is an environment comprised of good soil structure, soil chemistry, soil organisms, and organic matter. This ecological environment allows plant root development by providing the nutrients necessary for proper plant growth which results in profitable production. This environment must include a balanced supply of essential plant nutrients, water, air, organic matter, and beneficial soil organisms. A productive soil environment must be free of compaction and harmful chemical conditions such as excessive acidity, alkalinity, or harmful salts. It should also be void of, or low in, parasitic nematodes, harmful insects, and diseases.

Maintaining soil quality is important. Components of soil quality include soil tilth and soil health. Soil tilth (physical or structural aspects) is a key asset in helping agriculture producers maintain a competitive edge in worldwide agriculture. Soil health (biological

characteristics) is also vital in maintaining adequate production levels. Soil tilth and soil health can be improved over a period of time through the use of reduced tillage, favorable fertility, use of cover crops, animal manure or green manure, crop rotations utilizing forages or grasses, and reduced traffic over fields. In the past, soil tilth has been looked at in a physical sense, and we have not fully understood the impact of the biological and chemical reactions going on below ground.

A good soil contains 50% air space. In fact, adequate air is one of the missing ingredients in most soil preparation processes. The increased air space allows for an increase in the spreading of oxygen (which the roots and microbes depend on) into the soil, and the distribution of carbon dioxide (which leaves depend on). This increased "breathing" ability is a key to improved plant health.

Crop residue is a source of organic matter needed for soil maintenance. Natures composting of crop residue has a dual function. It improves the structure of the soil. Improved structure means the soil will be easier to work, will have good aeration and water retention characteristics, and will be resistant to erosion. This composting also provides nutrients for plant growth. Composting by nature keeps soil at maximum health with a minimum of expense. Organic material makes up between 1 - 8 percent of soil and is essential to the substance of soil life and fertility. A soil with good organic matter content soaks up rain like a sponge and regulates the supply to plants. Soil with little or no organic matter resists water penetration, thus leading to destructive compaction, erosion, flooding and crusting. A loose healthy soil assists in the spreading of air into the soil, plus helps in the exchange of nutrients and moisture.

Researchers are concerned about soil quality. The National Soil Tilth Laboratory at Iowa State University is searching for new answers to age-old questions about one of our country's most important resources -- our soil. The processes maintaining soil quality are a mysterious underground drama which currently poses as many questions as answers for the researchers. The ultimate goal of researchers at the National Soil Tilth Laboratory is to find out how all three factors -- the physical, chemical, and biological aspects of soil -- interact to create the living soil environment. Our present knowledge of this living world in the soil only scratches the surface. According to Jerry Hatfield, Director of the National Soil Tilth Laboratory at Iowa State University, his staff expects to develop a model to visually demonstrate where earthworms prefer to live and where they are most comfortable in the soil. Hatfield states, "I am convinced we can look at various tillage systems and residues and find how to manage earthworms for the best possible yields. We need to find what role earthworms are playing in soil formation. We know about the soil's physical properties and its chemistry. But we don't know much about adding biological factors to the soil."

Human Impact

People have been destroying fertile land for thousands of years. Destruction of the soil and of natural communities mark out the path of lost civilizations. Soil erosion is one of the chief factors in the destruction of soil. Most recently the North American continent has become an example of the rapid process of erosion.

Tillage may be considered as a means of temporary soil conditioning but does not take the place of natural soil development. Tillage leaves the soil temporarily looser. It increases the size of soil pores thus adding air and water penetration. It makes the soil more easily penetrated by roots. Tillage should not be expected to act as a substitute for permanent natural soil improvement. Tillage should only be performed when the soil is evenly moist, not too dry or moist. Digging a hard, dry soil breaks down the structure, and it is difficult to penetrate. Wet soil clings together and is easily compacted. Compaction destroys a friable structure and minimizes aeration. These conditions kill microbiotic life. Soil is too dry for tillage when it is loose and will not hold its shape after being squeezed in the palm of your hand (in the case of sands or loams) or when it is hard, dry and cannot easily be penetrated by a spade (in the case of clays). Soil is too wet when it sticks to a spade as you dig.

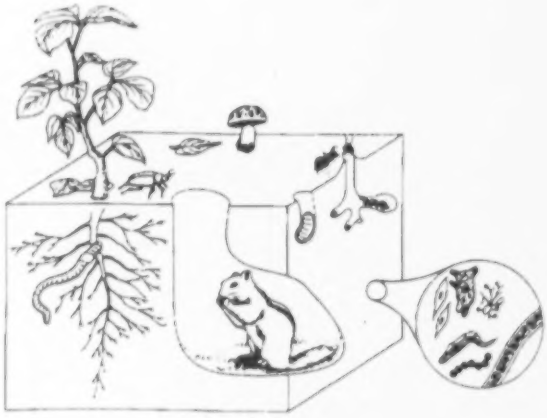
Advantages of reduced tillage or no-till include fuel savings, reduced soil compaction, less costly trips across the field, less machinery, labor saving, and soil saving. It generally takes three to five years before one can see the long term beneficial effects of no-till, but most benefits continue to magnify as time in no-till increases beyond five years. Soil structure improves steadily. Earthworm activity increases rather dramatically after the first three to five years. Surface organic matter increases and a surface mulch develops and thickens with time which increases biological activity. Earthworm holes and decaying roots develop many large (macro) pores throughout the soil profile -- usually to a depth of three to five feet if left undisturbed by tillage. These pores, in conjunction with the surface mulch, dramatically improve water infiltration, air, water, and root movement within the soil. Drainage in tilled soils or soils with good natural internal drainage improves with time in no-till soils. Phosphorus and potassium levels build up somewhat in the top three inches of the soil while pH level may drop somewhat in the six to nine inch level if anhydrous ammonia (NH_3) is continually applied to corn.

Annual weed pressure declines with time, but some perennial weeds may increase if not controlled. The combination of a thicker surface mulch and increasing soil porosity results in a dramatic reduction in water runoff and soil erosion. With reduced runoff, waterways and terraces do not need to be as wide or deep and require less maintenance. Wildlife populations will increase with time in no-till because of better cover.

Conservation practices that reduce tillage and leave crop residue on the soil surface can be used to help nature protect the living soil. Reduced tillage or no-till utilizes the crop residues as mulch. This mulch reduces evaporation from the soil surface. A high percentage of weed seeds are prevented from germinating and the soil is protected from the impact of raindrops and winter frost penetration. Microorganisms as well as earthworms remain active in the surface layer that is protected from drying out and from temperature extremes.

Life in the Soil

Our world is teeming with life, yet few of us know the creatures inhabiting the soil beneath our feet. Every acre of soil is home to two or more tons of living things under the soil surface. Organisms that inhabit the soil actively affect soil formation. Up to 100 million bacteria (simple one-celled organisms) may live in one teaspoon of soil. Along with bacteria, fungi act as the main soil decomposers. Up to 450,000 fungi may reside in a teaspoon of soil.



Actinomycetes produce the characteristic odor of damp soil. One teaspoon of soil contains about 12 million actinomycetes. Algae (single-celled organisms) live in water films. One teaspoon of moist soil is host for about 250,000 algae. These soil microbes help break down plant material into organic matter. However, many organism fulfill other tasks important to agriculture. Most microorganisms need air, water, and food to survive. These requirements compel the soil organisms to live near the soil surface. Soil organic matter and life can be seen as a means of nutrient storage. Soil microbes are important agents of soil aggregation (soil structure).

Earthworms are not much to look at, yet their ecological significance is both great and far-reaching. Charles Darwin, the great English naturalist who lived from 1809 to 1882, wrote a book about earthworms just one year before his death and in it he said: "It may be doubted if there are any other animals which have played such an important part in the history of the world as those lowly organized creatures." The earthworm is a simple animal. Its life is also simple. An earthworm tunnels, feeds, and mates. The earthworm and its way of life are very important to many kinds of life. In feeding, the earthworm breaks down plant and animal wastes. Some of this material is absorbed into the bloodstream and distributed to the earthworm's body; the rest passes out as waste called castings. These castings make fertilizer which is rich in nitrate, phosphate, and potash. It has been estimated that the 2 to 3 million earthworms living on one acre can produce up to 12 to 18 tons (about 11 to 16 metric tons) of castings in 45 days. Although earthworms help improve soil, they cannot change really bad soil.

Earthworms - Master Tillers

Practices that promote soil organic matter levels and structure are good for earthworms. Each day earthworms ingest as much as they weigh, converting organic matter and common soil into enriched castings containing as much as five times the nitrogen, seven times the phosphorus, eleven times the potassium, and fifty percent more bacteria than would otherwise be found in the soil. In the spring, farmers and gardeners the world over till their fields to loosen up the soil before planting. Well-tilled soil has many spaces where air and water can move and reach plant roots. In nature, most tillage is done by earthworms. They are the earth's living plows. Earthworms are at work in nearly all the land areas.

Earthworms exist in surprising large numbers. One acre of land may hold from 50,000 to one million earthworms. There are about 1,800 kinds of earthworms. The different kinds may be brown, purple, red, blue, green, or light tan. They also range greatly in size. The smallest are tiny inch-long worms while the largest are ten-foot-long giants of Australia and the tropics. All live underground. Many kinds live in the top eighteen inches of soil, but some burrow down as much as eight or nine feet.

Some of the common earthworm species as reported in an article by Ed Berry and Doug Karlen, **Comparison of Alternative Farming Systems: II**, *Earthworm Population Denisty and Species Diversity* are:

Lumbricus terrestris - feeds on top of soil surface on residue and maintains a permanent burrow system (nightcrawler).

Octolasion tyrtaeum - feeds below the surface on decomposed residue and does not maintain a permanent burrow system; dominat species across all tillage treatments.

Aporrectodea trapezoides - feeds below the surface on decomposed residue and does not maintain a permanent burrow system.

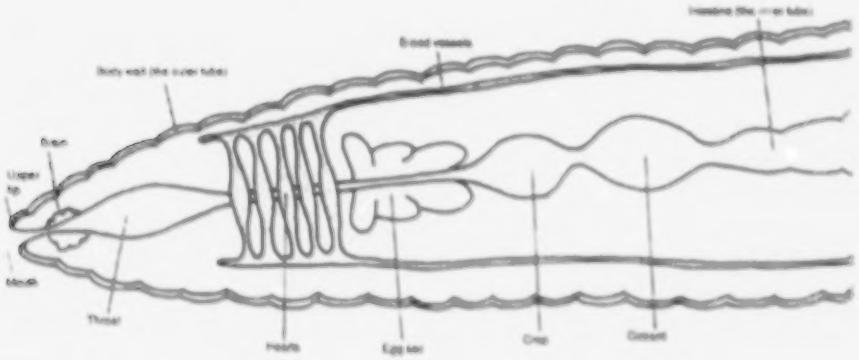
A. tuberculata - feeds below the surface on decomposed residue and does not maintain a permanent burrow system; predominant species in ridge tillage systems.

A. rosea - feeds below the surface on decomposed residue and does not maintain a permanent burrow system.

An earthworm can move a stone that is fifty times its own weight. In clay and other hard-packed soils, there are few if any spaces for the earthworm to wriggle through. Earthworms burrow in these soils by swallowing the soil. In this way, it makes its own space. Forty tons of soil a year may be turned over by the earthworms in one acre of land. Through their tunneling, earthworms loosen up the soil and so change the environment of all other soil-inhabiting organisms, including plant roots. Earthworms increase the volume of root material penetrating the soil. By swallowing soil, they turn it over, and by feeding on dead matter, they do something even more important. Earthworms help release minerals that plants need to put these back in the soil to be used again. Earthworms and other small forms of life in the soil are living recycling centers.

Earthworms use two sets of muscles to move. One set helps the earthworm become long and skinny then the other set of muscles causes the worm to become short and squat. By becoming short, then long, then short again, they inch their way through the soil. Earthworms also have hooks, setae (SEE-tay), to pull themselves along. Eight setae stick out of each segment of an earthworm and help the worm to grip sides of the tunnel as it pulls itself ahead and also hold on if something tries to tug it out of the ground. Earthworms don't have eyes, but can sense light through special cells in their skin. They don't like light, so they move away from it. They have no lungs but instead soak up air through their moist skin.

Earthworms (nightcrawlers) are nocturnal animals that come to the surface only after dark, they also do most of their feeding at night. Earthworms are big eaters. In one acre of forest land, they may eat ten tons of litter a year. In an orchard they may eat ninety percent of the fallen leaves in three months. The earthworm has a mouth but no teeth; therefore it cannot chew its food before swallowing it. Swallowed soil and food is pushed through the esophagus by muscles to a chamber or sac called the crop. The crop stores food for a short time; then the food passes into the gizzard. The gizzard has strong muscles which grinds the food, aided by tiny stones from the soil which the worm has swallowed with its food. Special glands in the intestine secrete juices to digest it. Some of the digested material is absorbed into the bloodstream and distributed to the earthworm's body while the rest is expelled as waste (castings).



Earthworms prefer well-drained but moist, fertile soils that contain plenty of organic matter such as mulch and manure. They prefer a neutral pH or almost neutral soils (5.5 - 7.0). Alfalfa and forage grasses support the highest earthworm populations. Medium-textured soil types that are neither extremely acidic nor alkaline support high populations while coarse-textured (sandy) soils support almost no earthworms. **Earthworm populations may be viewed as a visible sign of soil health because conditions in which earthworms thrive are also good for other soil flora, fauna, and plant roots.**

Red worms and common garden worms require 60 - 70° F, although they can withstand temperatures as high as 80° F. Night crawlers do not tolerate temperatures above 50° F. Earthworms are most active in late autumn and again in the spring. Populations peak in the summer. Dry summer weather will cause a decrease in numbers. Abundant ground cover and stable soil temperatures increase both worm activity and population. The addition of organic fertilizer materials stimulates certain earthworm species. Regular use of acidic fertilizers, such as ammonium sulphate, decrease earthworm populations and maintain the soil at a pH which discourages reinvasion by them. Several agricultural chemicals have a direct toxic effect on earthworms. In general, pesticides used to control animal organisms are highly toxic. Herbicides tend to be less toxic.

All of the farming practices that promote increased soil organic matter levels and structure are good for earthworms. According to Edwin C. Berry, Research Entomologist for the National Soil Tilth Laboratory at Iowa State University, evidence indicates that the absence of plowing and the abundant crop residue left on the soil surface creates a favorable environment for earthworms. These practices include crop rotation, minimum tillage, and additions of organic matter. Liming acid soils also helps. In the late fall, earthworms migrate deep into the soil for protection from the cold. On soils left bare over winter, the soil may freeze so rapidly and deeply as to kill many of them. Leaving soil covered with mulch or crop residue protects earthworms from winter kill.

Earthworms' activities help move chemical residues down through the soil and also aerate the soil which may also contaminate groundwater under certain conditions. Research is currently underway to determine the effect of this. According to William M. Edwards, Leader of Conservation Tillage in Coshocton, Illinois, small horizontal earthworm burrows may help water soak into the soil to be used by plants without moving it anywhere near the groundwater. "Increased infiltration also means less surface runoff is available to carry fertilizer and pesticides to lakes and stream," says Edwards. "Moreover, the burrows help provide soil aeration to accelerate microbial action speeding the breakdown of pesticides." The use of no-till does create a favorable environment for many earthworms. Surface residue left from no-till provides a major food source for earthworms (nightcrawlers), helping them form stable burrows that are open to the surface.

Earthworms are also beneficial to lawns. Earthworms (nightcrawlers) help prevent thatch buildup (a layer of dead grass that weakens turf) by feeding on it. Earthworms also help counteract the compaction common to lawns. Homeowners may object, however, to the piles of casts some species leave in the lawn. Earthworms may also attract moles whose burrows can severely damage a lawn.

Summary

Much can be said about the basic importance of the living soil and its importance to the world community. It provides people with a medium for food production, a necessary link between the environment and plants, with the raw materials necessary for filling material needs, and with opportunities for satisfactions dear to our heart. We often tend to take this relationship for granted. The basic and underlying significance of the living soil to mankind can never be gauged simply in terms of its relative economic contribution to a nation's economy.

The quality of agricultural soils is derived from their effectiveness as a medium that provides essential nutrients and water. Organic matter in soils influences plant growth in a number of ways. The greatest benefits of organic matter in soil are its water-holding capacity; the manner in which it alters soil structure to improve soil tilth; its high exchange capacity for binding and releasing some mineral nutrients; its presence as a food source for soil microorganisms that recycle soil nutrients; and its mineralization to nitrogen, phosphorus, and sulfur. The cycling of mineral nutrients between living organisms and dead organic components of the soil system provides an important reservoir of the elements needed in plant growth.

While the supply of cropland in the United States appears to be adequate at present, the demands on it are predicted to increase making it even more valuable than it is at present. Soil deterioration is not necessary. Good soil management, from the point of view of maintaining fertility and productivity, is based on a few relatively simple practices. These are correcting acidity if needed, capitalizing on the use of plant nutrients, maintaining the supply of organic matter, and using conservation practices to control erosion and protect water quality.

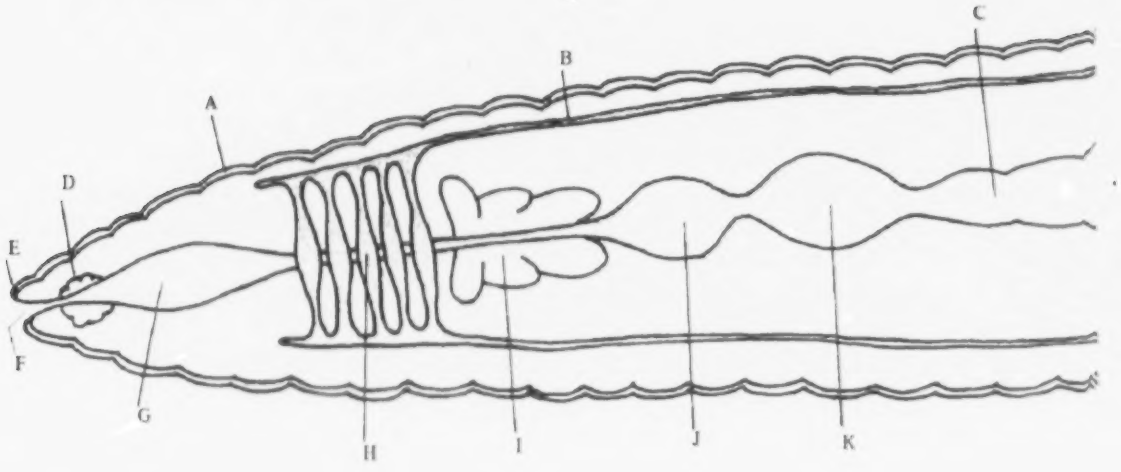
For too long, the concept of soil's linkage to the environment (that needs protection) has been neglected or misunderstood by society. It's time we acknowledge problems in the misuse of soil and study specifically what is happening beneath its surface. Society has attached great importance to living organisms on the Earth's surface, but much less attention has been given to the diversity and importance of living organisms in the soil. Our primary responsibility is to return to the soil the life it so generously shares with us and to ensure that life for generations to come. The only way to do this -- the only way to be certain that the soil will continue to feed a hungry world -- is to regenerate the soil to make the soil healthier, stronger, more durable, and better able to withstand the assault of nature and people. This modern environmental management is based on Aldo Leopold's "Land ethic" -- his concept of land health, its inherent tendency to produce life and society's responsibility to preserve it.

Prepared by Dr. Gaylan G. Scofield, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. February 1992.

Earthworm Body Part Identification

Instructions

Identify the earthworm body parts in the spaces provided below.



A. _____

B. _____

C. _____

D. _____

E. _____

F. _____

G. _____

H. _____

I. _____

J. _____

K. _____

Prepared by Dr. Gaylan G. Scofield, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. February 1992.

Living Soil Concepts

1. Define soil.

2. Name the two components of soil quality.

3. Describe how the two components of soil quality can be improved over a period of time.

4. Discuss the dual function of natures' composting of crop residue.

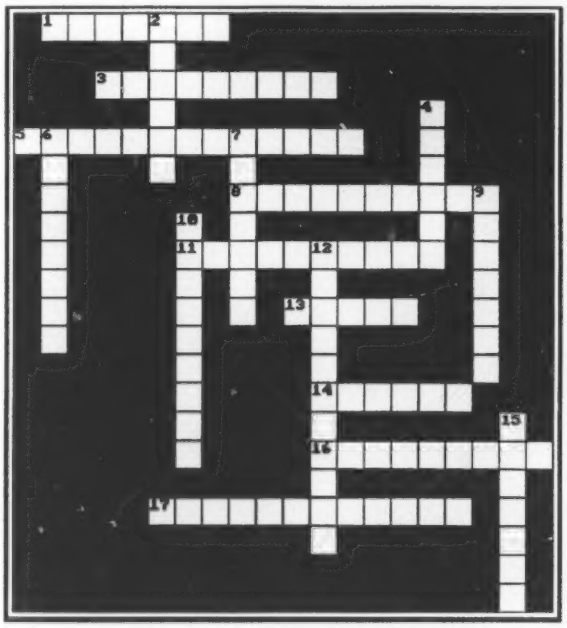
5. Tillage may be considered as a means of temporary soil conditioning. Describe how tillage harms the soil and living organisms.

6. Discuss the advantages of reduced tillage or no-till.

7. Compare/contrast the earthworm's internal body structure to other agricultural animals.

8. Describe ideal earthworm conditions.

Vocabulary Challenger Unit I-d



Across:

1. Readily crumbled soil.
3. Maybe the most important creature in the history of the world.
5. Microorganisms responsible for the earthy smell.
8. Biological degradation or breakdown of organic matter.
11. Relationship between organisms and the environment.
13. Small hooks on earthworm's body used to pull themselves along.
14. Serves as a lid to earthworm burrows.
16. Small worm-like animals that feed from plant roots and other organisms.
17. Large earthworm that burrows vertically.

Down:

2. Earthworm tunnel.
4. Planting without disturbing the soil.
6. Earthworm waste product rich in nitrate, phosphate, and potash.
7. Contains baby earthworms.
9. Organ where the earthworm's food is ground.
10. Neither acid or alkaline.
12. Crop tilled into the soil which adds nitrogen and organic matter.
15. Smaller earthworms that burrow horizontally.

Prepared by Annette Kiefer, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. May 1993.

Knowledge Builder
Unit I - d

1. Match the following terms with their correct definitions.

___ Actinomycetes	___ Green Manure
___ Burrow	___ Midden
___ Castings	___ Nematode
___ Cocoons	___ Neutral pH
___ Composting	___ Nightcrawler
___ Earthworm	___ No-till
___ Ecological	___ Reduced Tillage
___ Friable	___ Reduced Traffic
___ Gizzard	___ Setae

(a) Larger earthworms which burrow vertically and feed on surface residue at night.
(b) Tillage which leaves at least 30% of residue coverage on the soil surface before planting.
(c) A group of microorganisms which are active in decomposing and responsible for the earthy smell of compost.
(d) A group of small worm-like animals which commonly inhabit soils and feed from plant roots and other organisms.
(e) Neither acid or alkaline.
(f) Planting without disturbing the soil.
(g) The biological degradation or breakdown of organic matter by a managed process.
(h) Waste product rich in nitrate, phosphate, and potash.
(i) Lid to the earthworm's burrow.
(j) Keeping wheel tracks in the same location to allow natural soil development.
(k) A crop tilled into the soil to add nitrogen and organic matter.
(l) Relationship between organisms and the environment.
(m) Readily crumbled soil.
(n) Earthworm tunnel.
(o) Contains baby earthworms.
(p) Maybe the most important creature in the history of the world.
(q) Body part of an earthworm that is used to pull it along in their burrows.
(r) Organ where the earthworms food is ground.

2. Why are earthworms an indicator of good soil health?

3. Why is it important to leave crop or plant residue on the soil surface?

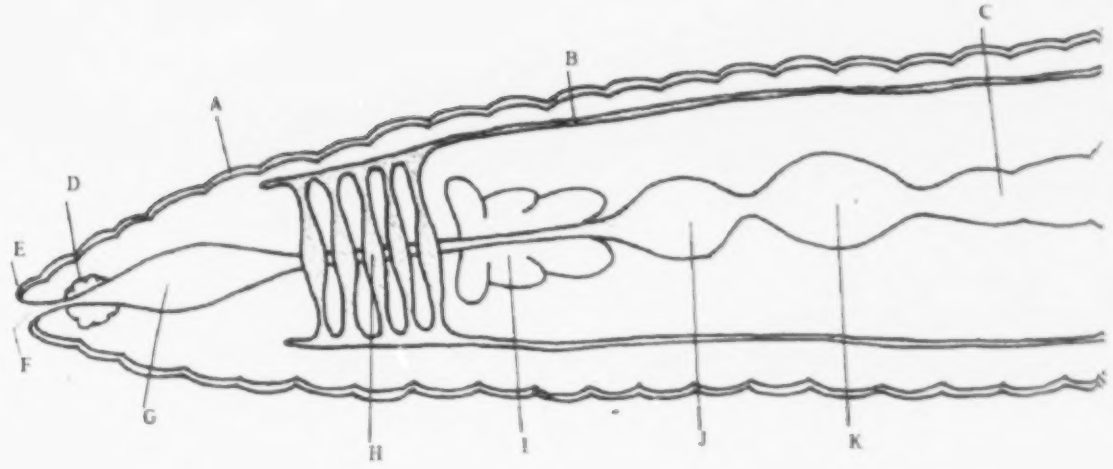
4. How do humans impact the living soil?

5. Compare/contrast the body parts of an earthworm to other agricultural animals.

6. Write 1 or 2 paragraphs on your land ethic.

7. Draw a picture of the living soil.

Earthworm Body Part Identification



A. Body Wall

B. Blood Vessels

C. Intestine

D. Brain

E. Upper Lip

F. Mouth

G. Throat

H. Hearts

I. Egg Sac

J. Crop

K. Gizzard

Prepared by Dr. Gaylan G. Scofield, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. February 1992

Summary

- ✓ **Soil is a complex network of living things dependent on each other for survival**

- ✓ **Correct land management protects and enhances our soil while maintaining a suitable environment for life (microbes and earthworms) that live there**

- ✓ **Soil is earth's most valuable resource, which directly or indirectly provides food we and other animals need to stay alive and healthy**

Prepared by Dr. Gaylan G. Scofield, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. February 1992

Summary

- ✓ **Earthworms are an indicator of good soil quality**
- ✓ **Proper soil, insect, and plant management practices are needed to maintain ample earthworm numbers**
- ✓ **People do not fully realize that soil organisms help to make soil productive**

Prepared by Dr. Gaylon G. Sutfield, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. February 1992.

Earthworms and Soil Mixing

Introduction

Earthworms are very busy creatures. They can move considerable amounts of soil if given half a chance. This exercise is a demonstration that you can do to show what earthworms can do in the soil environment.

Objective

Participants will be able to describe the importance of soil mixing by earthworms.

Competencies

1. Explain the benefits derived from earthworms in our living soil.
2. Organize thoughts and clearly express point of view.

Materials

1. One quart jar with lid or aluminum foil over the top (could be larger if you choose).
2. Two kinds of soil that have different colors (light and dark). The easiest way to do this is to take a sample of the surface soil and dig down to get a sample at the subsoil.
3. Opaque paper.
4. Two earthworms.
5. Grass clippings or other earthworm "food" (cornmeal, vegetable peelings, etc.).

Procedure

1. Add enough light-colored soil to fill the jar one-third full. Then place an equal amount of dark-colored soil on top.
2. Add a small amount of grass clippings or other food on top of the soil.
3. Place the opaque paper around the outside of the jar so that the soil inside is completely covered. This will create dark conditions that will make the earthworms feel at home. Put a lid or aluminum foil on top of the jar, with several air holes in it.
4. Place the earthworms in the jar and allow them to operate for several days. You can check on their progress periodically by removing the opaque paper and then replacing it. You should moisten the soil slightly every other day.

Conclusions

Prepared by Gary Steinhardt and Eileen Kaldivko, Agronomy Department, Prude University, West Lafayette, Indiana.
Edited by Dr. Gaylan G. Scofield, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. February 1992.

Earthworms and Plants

Introduction

Earthworms and other small forms of life are living recycling centers. As the soil and the remains of plants and animals pass through the worm's long body, it is cast out the back end as waste. This waste is called casts. By tunneling, earthworms loosen the soil. Earthworms feed on litter, and their feeding breaks it down. Their feeding releases the minerals in a form the plants can use.

Objective

Participants will be able to understand how earthworms help promote successful plant/crop growth.

Competencies

1. Explain limiting factors of successful plant/crop growth.
2. Follow directions correctly.
3. Maintain clean and orderly work area.

Materials

1. Three containers suitable for growing bean plants.
2. Bean seed.
3. Potting soil.
4. Earthworms.

Procedure

1. Prepare each container with soil and one bean seed.
2. Water thoroughly with the same amount of water.
3. Add partially decomposed organic matter to the soil surface of two containers.
4. Add two to four earthworms (depends on size of container) to one container. Make sure the worms are below the organic matter. Place aluminum foil with a few air holes over the soil to contain the worms.
5. Put the pots side by side and water with the same amount of water -- always at the same time. Check frequently.
6. After a month or two, observe and note differences in plant characteristics as growth occurs.

Conclusions

Prepared by Dr. Gaylan G. Scofield, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. February 1992.

Composting with Earthworms

Introduction

Composting is the biological decomposition of organic matter. Naturally occurring microorganisms and tiny invertebrate animals are the primary agents of physical decay helping to break up waste debris and transport microorganisms from one site to another.

Objective

Participants will understand the fundamentals of composting.

Competencies

1. Describe basic soil biology principles.
2. Define the role of earthworms and microbes in the soil.

Materials

1. Container with lid (2' x 4' x 2') with 10 - ½" drainage holes or large aquarium with a 1" layer of small stones (1 lb. food waste/week requires 1 square foot of surface area).
2. Soil, small stones, and water.
3. "Redworms" (red wigglers), earthworms, or night crawlers (2 lbs. per 1 lb. garbage).
4. Vegetable, fruit scraps, or other suitable waste.

Procedure

1. Use a 1" layer of small stones in the bottom or drill holes for drainage.
2. Moisten soil to achieve a 75% water content by weight (dry material weight multiplied by 3 equals weight of water to add).
3. Fill container ⅓ full with the damp soil and allow excess moisture to drain (1-2 hrs.)
4. Place earthworms on soil surface and allow them to move into the soil. Duplicate the lab using common garden earthworms or night crawlers. Compare the results.
5. Add additional soil to within 3" from the top of the container.
6. Place vegetable and fruit scraps at one end of container and cover with soil. Do not add inorganic or potentially hazardous materials. Add to the compost pile weekly.
7. Keep your compost pile moist -- but not wet. Keep soil over the compost pile to reduce problems with flies. Flypaper may be used inside the container if flies are a problem.
8. Start a new compost pile on opposite side of the container every 3-5 months. Within 1 month, the earthworms will move to the new compost site and the "old" site can be harvested and used in potting mixtures. Prepare new soil as instructed in #2 and then add to the "old" site.

Conclusions

Prepared by Dr. Gaylan G. Scofield, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. February 1992.

Earthworm Tolerance to Chemicals

Introduction

The widespread utilization of chemicals over the past few years has raised many questions about their toxicity. As a rule, we consider earthworms beneficial in increasing the porosity of the soil. One question that remains is, "How toxic are these chemicals to earthworms?" One chemical, Atrazine, has been used by farmers to help control weeds. By completing this lab, you should be able to determine how toxic this chemical is to earthworms.

Objective

Participants will determine what concentration of atrazine is toxic to earthworms.

Competencies

1. Conduct a research project.
2. Analyze data collected.
3. Make recommendations based on conclusions.

Materials

1. Rubber gloves.
2. Plastic bottles (7 2-litter and 1 1-litter).
3. 5 pounds of earthworm bedding.
4. Clean water.
5. 36 earthworms.
6. Eye dropper.
7. Balance.
8. Safety glasses.

Procedure

1. Review the atrazine label to determine how to properly handle the chemical. Write a brief statement in regard to "Can atrazine affect soil life?"
2. **Review the following safety items before continuing. If you have questions, ask your instructor.**
   Wear a lab coat or other suitable protective clothing.
   Wear safety glasses or face shield to protect your eyes.
   Wear rubber gloves.
   Use lab equipment correctly.
3. Prepare a stock solution of atrazine at a field ration (12 grams/liter). Allow the atrazine to dissolve. **(Use extreme caution and follow proper safety procedures when working with chemicals).** Other chemicals commonly used for lawn, garden, and agriculture may be used.
4. Remove the tops from 7 2-litter bottles, rinse, and number from 1 to 7.
5. Place 113.5 g of worm bedding in each bottle.

6. Add 250 ml of water to bottle #1 and mix with the worm bedding..
7. Add 1 drop of atrazine solution to 250 ml of water and mix with the worm bedding in bottle #2.
8. Repeat step 7 for the remainder of the bottles (3 - 7), varying the amount of atrazine added as follows: bottle #3 = 2 drops, bottle #4 = 4 drops, bottle #5 = 6 drops, bottle #6 = 8 drops, bottle #7 = 10 drops.
9. Place 6 healthy earthworms in each bottle.
10. Store in a dark, cool place. Check and record the results on day 3 and day 7 in the chart below.

Conclusions

1. Record your observations on day 3 and day 7. **Use adequate safety precautions when handling the chemically treated worm bedding**.

Bottle Number	Day 3 - Number live earthworms	Day 3 - Comments	Day 7 - Number live earthworms	Day 7 - Comments
Bottle # 1				
Bottle # 2				
Bottle # 3				
Bottle # 4				
Bottle # 5				
Bottle # 6				
Bottle # 7				

2. Analyze and explain differences observed during your research. Include data in your explanation.

3. What are your recommendations for the application rate of atrazine? Explain your answer using your findings.

Source: Richard Seidel and Julie Healy, Agriscience Teacher Interns, University of Illinois, Department of Agronomy. 1992.
Prepared by Kenneth L. Wise, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. February 1993.
Edited by Dr. Gaylan G. Scofield, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. May 1993.

Earthworm Burrows

Introduction

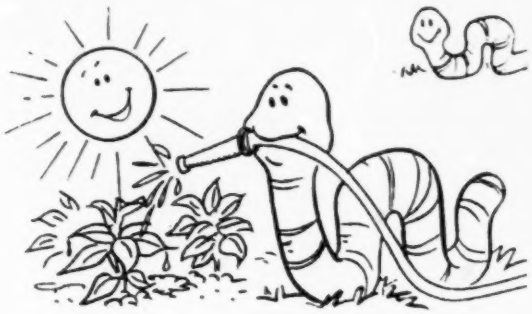
Earthworms are the earth's living plows and are at work in nearly all the land areas of the world. Earthworm burrows provide spaces for air, water, nutrients, and plant roots in the soil.

Objective

Participants will understand the importance of earthworms and their burrows.

Competencies

1. Describe the role of earthworms.
2. Conduct a research project.
3. Organize thoughts and clearly express point of view.



Materials

1. Three feet of 6" pvc plastic pipe that has been cut into 6" lengths.
2. Duct tape.
3. Soil.
4. Six to ten earthworms.
5. Earthworm food (decomposed organic matter).
6. Plywood square 12" x 12".

Procedure

1. Assemble the pvc pipe sections using duct tape.
2. Place the assembled pvc pipe on the plywood base.
3. Add moist soil until it is 3" from the top. If moisture must be added, mix well before placing in the pipe.
4. Place earthworms on top of the soil.
5. Add earthworm food.
6. Check daily the supply of food and moisture content of the soil. Add each as needed.
7. After two weeks, untape the pvc pipe sections and snap the sections apart.
8. Carefully push the soil from the pipe sections.
9. Observe the burrows. If necessary, remove soil from the sides until burrows are found.
10. Pour a small amount of water on a section and observe how the water infiltrates the burrows.

Conclusions

Prepared by Dr. Gaylan G. Scofield, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. February 1992.

Earthworms and Soil Structure

Introduction

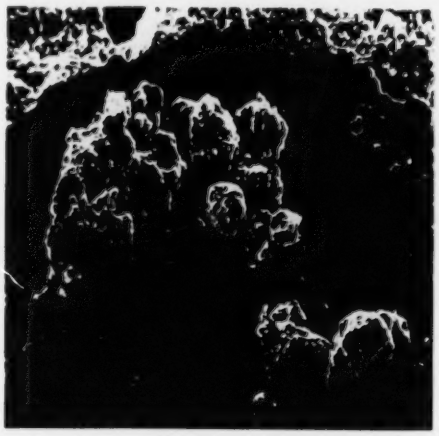
Although earthworms help improve soil, they cannot change really bad soil; as a matter of fact, they will not even live in it. Earthworm waste is called castings. These castings act as fertilizer which is rich in nitrate, phosphate, and potash. It has been estimated that the 2 to 3 million earthworms living on one acre can produce up to 12 to 18 tons (about 11 to 16 metric tons) of castings every 45 days.

Objective

Participants will understand how earthworms help improve soil structure.

Competencies

1. Explain the impact that earthworms have on soil structure.
2. Define the role of earthworms in the soil.



Fecal pellets of earthworms, magnified 10,000 times by a scanning electron microscope. (Photo by Hari Eswaran)

Materials

1. Earthworm castings.
2. Pain grass sod.
3. Two glasses containing water.

Procedure

1. Fill two glasses with water.
2. Drop a worm casting into one and a little piece of plain sod of the same size into the other.
3. Observe the differences in breakup.

Conclusions

Prepared by Dr. Gaylan G. Scofield, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. February 1992.

Earthworms and Residue Utilization

Introduction

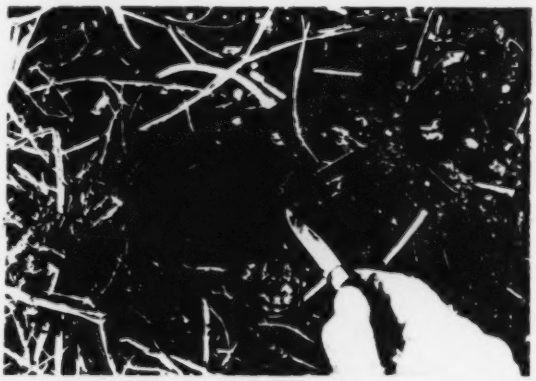
Simply leaving crop residues in the soil is an easy way to provide organic matter. Only a little organic matter is found in most mineral soils, but its effect on the soil is great. Organic matter is that portion of the soil that includes animal and plant remains in various stages of decay. Earthworms help improve soils by utilizing crop residue as food and breaking them down.

Objective

Participants will demonstrate how earthworms use residue.

Competencies

1. Explain the impact that earthworms have on residue utilization.
2. Define the role of earthworms utilizing residue.



Crop residue utilized by earthworms in forming a midden. (Photo by Gary Huber)

Materials

1. 12" x 12" x 8" container.
2. Soil.
3. 3 kinds of residue.
4. 10 - 15 earthworms.

Procedure

1. Fill the container with moist soil.
2. Add earthworms to one end.
3. Place residue on opposite end.
4. Place container in a dark cool area.
5. Add water as needed to maintain suitable moisture for earthworms.
6. Observe the piles of residue over a period of time (2 - 3 weeks).
7. Observe the middens created by the earthworms.
8. Add a small amount of water next to a midden. Observe how the water soaks into the soil. Repeat in an area with no middens. Why is there a difference?
9. Why has the residue moved?

Conclusions

Prepared by Dr. Gaylan G. Scofield, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. February 1992.

Composting with a Wiggle

Introduction

Raising earthworms in a bottle or other suitable container allows us to witness their role in decomposition and recycling. It gives us insight into the life cycle of some fascinating animals. The term vermicomposting comes from the latin vermis meaning worm, literally, vermicomposting means worm composting.

Objective

Participants will understand the importance of earthworms in their crucial role of breaking down organic materials.

Competencies

1. Explain the value of vermicomposting.
2. Follow directions and construct experiment bottle.

Materials

1. 1 2-liter bottle and 1 bottle base from an additional bottle.
2. Newspaper, scissors, grease pencil, razor blade, nails, and heat source.
3. Redworms (can be ordered from Flowerfield Enterprises, Kalamazoo, MI - 616-327-0108 or from most bait shops).
4. **LAB-INFO-1** (Bottle Basics Preparation Sheet).

Procedure

1. Prepare beverage bottle as directed in **LAB-INFO-1** (Bottle Basics Preparation Sheet)
2. Cut the bottle top from the bottle about 1 cm above the shoulder.
3. If your bottle has an attached base, cut down about 3 inches into the base -- keeping it glued to the bottle -- and continue cutting around the circumference until you remove the 3 inch portion. This cut makes more of the column visible. Be sure not to cut into the base bottom -- if you do this, the column will have stability problems.
4. Melt four 0.5 cm holes with a large, hot nail in the ring around the base for drainage. These holes should be placed low enough on the bottle so excess liquid can drain out the column. **(Use a plier and extreme care when handling hot nail.)**
5. Melt one or two rows of six to ten 3 mm holes (using a smaller **hot** nail) around the bottle to provide the necessary aeration.
6. Use the second bottle base as a lid for the column.
7. Cut a piece of dark colored paper about 4 cm taller than the finished bottle and wide enough to encircle the entire column. Earthworms are creatures of the dark and will avoid light. The paper screen will keep them happy and in the dark.

8. Identify the type of earthworm bedding you will use. Many types of bedding can be used -- shredded leaves, peat moss, or straw. A commonly used bedding is newsprint -- it is clean and readily available -- but don't let this keep you from experimenting with your own bedding mixtures!
9. Prepare the bedding by tossing it like a fresh green salad. This will allow all parts to become moist and eliminate clumps. Moisten the bedding in a bowl or a bucket using 2-3 cups of water, adding more water if necessary. Knead the water into the bedding until it is saturated. Drain the bedding by gently squeezing out excess water and then re-toss it vigorously. The bedding will need to be kept moist, but not in excess.
10. Mix a few tablespoons of soil into the bedding to inoculate it with natural soil microorganisms which hasten breakdown and improves the quality of the bedding.
11. Check the pH of your bedding. Earthworms prefer a near neutral or slightly basic pH (6.5 - 8.5). Mix some powdered lawn lime or finely crushed eggshells into the bedding if a litmus paper test indicates that your bedding is to acidic.
12. Fill the bottle ⅔ full with the moist (but fluffy) bedding.
13. Place 15-20 earthworms on top of the bedding and allow them to burrow into the bedding. Keep the temperature of your column within 20-30° C.
14. Add organic food every 3-4 days. Earthworms need 2-3 times their mass of food every few days. Place the food directly on the bedding and then cover with about 1-2 cm of moist bedding.

Conclusions

Source: **Bottle Biology Projects**, Department of Plant Pathology, University of Wisconsin-Madison, 1630 Linden Drive, Madison, Wisconsin 53706, (608) 263-5645, FAX (608) 263-2626.
Prepared by Douglas A. Wirth, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. March 1993.
Edited by Gaylan G. Scofield, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. May 1993.

Bottle Basics Preparation Sheet

Introduction

Plastic beverage bottles provide the primary material for **Bottle Biology** explorations. These information sheet shows you how plastic bottles can be taken apart, cut, and connected. Once these techniques are masted, you can use your imagination to combine bottles and parts of bottles into the apparatus for fascinating projects in the life sciences. Follow the steps below carefully in preparation of your bottles.

Procedure

1. Remove the bases from two bottles and the labels from all three.

   - Fill the bottle about ¼ full with very **hot** water (**use caution when using hot water**). If it is too hot (170-212° F) the plastic will soften, warp, and may permanently crumple. Screw the cap back on firmly. This will retain pressure inside the bottle, allowing you to hold the bottle tightly without crushing or denting it.

   - Tip the bottle on its side so the water warms the area where the label is attached -- this will soften the glue. Gently peel the label from the bottle. If there is resistance, you may need hotter water.

   - To remove the base, tip the bottle upright so the hot water warms the glue holding the bottle bottom to the base.

   - Remove the cap and pour the out slowly to avoid buckling the sides.

   - Usually most of the glue from the label and base is left on the bottle. It can be removed by scraping with a sharp-edged piece of metal or plastic while the glue is still warm. It can also be chemically removed with a solvent such as cleaning fluid. When using a solvent, put a small amount on a paper towel and rub. This works best if most of the glue has been removed by scraping. **Be sure there is adequate ventilation when using a solvent**.

   - Save all parts -- bottle, cap, and base. You now have the raw materials to begin fascinating explorations.

Source: **Bottle Biology Projects**, Department of Plant Pathology, University of Wisconsin-Madison, 1630 Linden Drive, Madison, Wisconsin 53706, (608) 263-5645, FAX (608) 263-2626.
Prepared by Douglas A. Wirth, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. March 1993.
Edited by Dr. Gaylan G. Scofield, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. May 1993.

Earthworm Farm

Introduction

Commercial earthworm farms are big business. They are located mostly in the warmer parts of the United States where the earthworms can live outdoors year round. An earthworm farm may sell an average of 750,000 earthworms a week, and as many as 700,000 per day during peak seasons.

Objective

Participants will construct an earthworm farm and raise earthworms.

Competencies

1. Explain the process of raising earthworms.
2. Follow directions.

Materials

1. Container 18" wide, 15" long, and 7" high or of suitable size.
2. Window screening, newspaper, or burlap.
3. Sand, soil, organic matter, and peat moss.
4. Earthworms (20 - 25 adult earthworms).
5. Earthworm food (poultry mash, cornmeal, leafy vegetables, grass cuttings, etc.).

Procedure

1. Construct or obtain a box 18" x 15" x 7".
2. Drill a few small ¼" drainage holes in the bottom and line it with window screening.
3. Place 5 - 6 pages of newspaper over the window screening.
4. Mix equal amounts of sand and rich soil and fill the box ⅔ full with the mixture.
5. Place a layer of well-rotted leaves mixed with peat moss on top of the soil mixture.
6. Moisten it all with water and put the earthworms on top (20 - 25 adult earthworms).
7. Cover the earthworm culture with damp burlap or moist newspaper to prevent it from drying out too quickly.

8. Sprinkle a thin layer of poultry mash, cornmeal, or other suitable earthworm food on top of the soil and scratch it in lightly.
9. Observe daily. Do not feed too much; start with just a little, and if it is eaten within a few days, you can increase the amount slightly. Never let the soil dry out, but don't keep it soaking wet. Use a plant mister and dampen the soil daily.
10. After a period of time (2 - 3 months) remove the large earthworms and place them in a new box. Continue to feed the baby earthworms and watch them grow.

Conclusions

Earthworm Intelligence

Introduction

Earthworms have a well-developed nervous system, five hearts, and a very small brain. Although the earthworm's brain is tiny and primitive, it can be used to a certain extent. "Intelligent" is really not the right word to describe the actions of an earthworm, and yet even such a simple creature is capable of learning.

Objective

Participants will observe the intelligence of an earthworm.

Competencies

1. To describe the reaction of the earthworm in an intelligence test.
2. To follow directions.

Materials

1. 1 Y- or T-shaped test tube, or a test-tube connector that will form a Y or a T.
2. 8 - 10" (about 20 - 25 cm) of clear plastic tubing big enough for an earthworm to crawl through.
3. Cotton or cork to block test tube opening.
4. Moist soil containing organic matter.
5. Earthworms.

Procedure

1. Attach the clear plastic tubing to the Y- or T-shaped test tube.
2. Place a piece of cotton or cork in one upper arm of the Y or T to block the exit.
3. Set the unblocked arm into a small pile of good moist soil.
4. Wet your earthworm a little so that it can slide easier, and place it headfirst into the bottom part of the tubing.
5. Observe the number of trails and errors it takes the earthworm to escape into the soil.
6. Keep the earthworm moist during the tests.

Conclusions

Prepared by Dr. Gaylan G. Scofield, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. February 1992.

Earthworm Food Preference

Introduction

Earthworms (nightcrawlers) are nocturnal animals that come to the surface only after dark, where they collect food and return under the soil's surface to feed. It is hard to believe, but an earthworm has taste cells and shows a definite preference for certain foods.

Objective

Participants will determine food preference of earthworms.

Competencies

1. To identify food preference of earthworms.
2. To record and explain observations.

Materials

1. Earthworms.
2. Earthworm food (celery leaves, carrot tops, cabbage leaves, etc.).
3. Containers with soil suitable to house earthworms.

Procedure

1. Prepare a long flat container containing suitable soil and several earthworms (4 - 10 depending on size of container).
2. Moisten the soil slightly.
3. Place the earthworms at one end of the container and little pieces of the food sources at the other.
4. Cover the container with a suitable top to contain the earthworms. To enhance earthworm activity, place the container in a dark location.
5. Observe after a few days. Add moisture to keep the soil damp and food as needed.

Conclusions

Prepared by Dr. Gaylan G. Scofield, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. February 1992.

Earthworm Sensitivity

Introduction

An earthworm has no eyes or ears, yet it can "hear" very well and "see" all it needs to see. This is because the earthworm has light-sensitive cells which are located in the front and tail ends of the animal. The absence of ears does not seem to bother the earthworm. What it lacks is accommodated for in it's extreme sensitivity to sound vibrations, touch, and light.

Objective

Participants will test the sensitivity of earthworms.

Competencies

1. Understand and explain earthworm sensitivity.
2. Follow directions.

Materials

1. Earthworms.
2. Two flashlights (one with a clear lens, one with the lens covered with green or red tissue paper or cellophane).
3. Heavy string to suspend the flashlights downward.

Procedure

1. Suspend two flashlights about 15 - 20 inches above a smooth-surfaced board or table. The lights should be about 2 feet apart. Cover one of the flashlights with green or red tissue paper or cellophane, leaving the other light uncovered.
2. Place a few earthworms under or near the clear beam and watch them wiggle quickly toward the red or green area, away from the clear white light.
3. Now try the reverse. Place the earthworms under the colored light. They probably will move in all directions or bunch together, but will avoid the clear beam area.
4. If you see that your earthworms are getting dry during the experiment, moisten them with water.
5. Worms are sensitive to touch. Poke one just a little and note the earthworm's reaction.
6. Earthworms have a top side and a belly side. Turn an earthworm over and observe it right itself immediately.

Conclusions

Prepared by Dr. Gaylan G. Scofield, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. February 1992.

Unit I - e
Exploring Earthworm Management

Introduction

Earthworms provide an ecological significance that is both great and far-reaching. Earthworms can be considered as living recycling centers. Earthworms have a major impact on soil fertility by incorporating organic matter, forming water-stable aggregates, increasing the availability of nutrients to plants, turning over the soil, increasing soil drainage, and improving aeration. With proper help, the earthworm will continue to help us.

Objective

Participants will be able to identify suitable management practices that enhance earthworm populations and improve soil productivity.

Competencies

1. Demonstrate how to determine earthworm populations.
2. Explain the benefits derived from earthworms in our living soil.
3. Conduct a research or demonstration project.
4. Select and explain suitable management practices that increase earthworm populations.

Materials

1. 4 5-gallon containers, several 1-gallon containers, 2 55-gallon containers.
2. Nightcrawlers, redworms.
3. Electric drill with ¼" drill bit, shovel, garden fork, tape measure, wooden stakes, mallet, sledge hammer, 4' plank.
4. Grease marker, tweezers, county soil survey.
5. Soil, organic matter (earthworm food), water.
6. 40% stock solution of formaldehyde.
7. 6 sheet metal squares 12" x 12" x 3" or wooden squares 12" x 12".

Information

INFO-SOIL-11 The Amazing Earthworm
INFO-SOIL-12 Onsite Sample Evaluation & Comparison
INFO-SOIL-13 Earthworm Population & Tons of Soil Processed Chart

Activities

ACT-SOIL-16 Earthworm Population Activity 1
ACT-SOIL-17 Earthworm Population Activity 2
ACT-SOIL-18 Earthworm Population Activity 3
ACT-SOIL-19 Earthworm Population Activity 4
ACT-SOIL-20 Unit I Evaluation

Lab

LAB-SOIL-13 Earthworm's Effect on the Soil Lab Exercise
LAB-SOIL-14 Earthworm's Effect on the Soil Field Exercise
LAB-SOIL-15 Onsite Sample Evaluation and Comparison

Teaching Procedure

1. This unit provides a "hands-on" approach allowing the participant to apply the knowledge gained in Units a-d. Provide copies of **INFO-SOIL-11** (The Amazing Earthworm) to participants. Review the content with participants.

2. Discuss the importance of earthworm populations with participants. Review the process of determining earthworm populations. Assign **ACT-SOIL-16 - 19** (Earthworm Population Activity). Explain to participants that information contained on the activity sheets is actual data collected from an Iowa farm.

ACT-SOIL-16 Earthworm Population Activity 1

	Field 4	Field 6	Field 8	Field 9
Worms/acre	1,916,640	348,480	566,280	740,520
Tons Soil	230.00	41.82	67.95	88.86

ACT-SOIL-17 Earthworm Population Activity 2

Field 4B	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6
Worms /acre	566,280	566,280	435,600	2,570,040	2,090,880	1,916,640
Tons Soil	67.95	67.95	52.27	308.40	280.91	230.00

ACT-SOIL-18 Earthworm Population Activity 3

	Field 5B Sample 1	Field 7B Sample 1	Field 5B Sample 2	Field 7B Sample 2
Worms/acre	2,003,760	3,920,400	1,350,360	1,219,680
Tons Soil	240.45	470.45	162.04	146.36

ACT-SOIL-19 Earthworm Population Activity 4

Field 3N	Sample 1	Sample 2	Sample 3
Worms/acre	740,520	1,263,240	2,831,400
Tons Soil	88.86	151.59	339.77

4. Assign **LAB-SOIL-13** (Earthworm's Effect on the Soil Lab Exercise) individually or to small groups for completion. Have participants share their findings with the class.

LAB-SOIL-13 Earthworm's Effect on the Soil - Lab Exercise

Earthworms have a major impact on soil conditions. Containers with earthworms will normally have better drainage and increase aeration. Some forms of earthworm food (organic matter) is more desirable than others.

5. Assign **LAB-SOIL-14** (Earthworm's Effect on the Soil Field Exercise) to small groups for completion. Have participants share their findings with the class.

LAB-SOIL-14 Earthworm's Effect on the Soil - Field Exercise

Earthworm burrows affect soil structure. The extent of earthworm activity can be correleated to the soil infiltration rate. Earthworm populations may be viewed as a visible sign of good soil health. Increased earthworm activity (burrowing) improves soil structure and drainage while increase aeration.

6. Provide participants with **INFO-SOIL-12** (Onsite Sample Evaluation & Comparison). Review key concepts for onsite sample evaluation and comparison.

7. Assign **LAB-SOIL-15** (Onsite Sample Evaluation and Comparison) to small groups for completion. Have participants complete the data sheet and share their findings with the class. **INFO-SOIL-13** (Earthworm Population and Tons of Soil Processed Chart) may be used to determine populations and tons of soil processed.

LAB-SOIL-15 Onsite Sample Evaluation and Comparison

Earthworm populations may be viewed as a visible sign of good soil health. Human activity such as tillage, crop rotations, and application of pesticides and fertilizers help or hinder earthworm populations. Typically, large earthworm populations can be observed in no-till fields and grass or legume areas. Earthworms favor longer crop rotations. The application of some insecticides may be harmful to the earthworm. If earthworms come in direct contact with anhydrous ammonia they will receive a burn just like humans. Earthworms prefer well-drained, fertile soils that contain plenty of organic matter.

6. Use **ACT-SOIL-20** (Unit I Evaluation) to determine participant knowledge of Unit I.

I. Match the following terms to the correct definitions.

1.	o	actinomycetes	14.	b	nutrient cycle
2.	e	aeration	15.	l	organic matter
3.	p	burrow	16.	i	permeability
4.	q	castings	17.	w	red worm
5.	r	cocoons	18.	y	reduced tillage
6.	u	composting	19.	x	setae
7.	m	crop rotation	20.	n	soil fauna
8.	s	earthworm	21.	c	soil flora
9.	k	integrated pest management	22.	g	soil organisms
10.	a	microbes	23.	h	soil structure
11.	t	midden	24.	d	sustainable agriculture
12.	v	nightcrawler	25.	j	symbiosis
13.	z	no-till	26.	f	texture

II. Answer the following in detail.

27. Why is soil the earth's most valuable resource?

The earth's thin layer of soil provides nutrients for plants which directly or indirectly provide the food we and other animals use to stay alive and healthy. The process of rebuilding soil is a lengthy process.

28. Why are earthworms an indicator of good soil quality?

If you have high numbers of earthworms, the soil conditions are suitable for other organisms. Microorganisms along with earthworms are needed for residue breakdown. Large numbers of earthworms help improve soil tilth with their burrowing.

29. Is the living soil as important in one part of the world as another? Why?

Where ever we are in the world, soil is the key link between plants and animals. The living organisms that make up the soil are the recycling process, key to providing food for plants and the plants provide food for animals.

30. Explain the message contained in *The Earthworm Song*.

Earthworms help maintain our healthy, fertile soil. Earthworm burrows bring air and water underground for plant use. Other organisms in the soil help maintain quality soil.

31. Explain how earthworms provide habitat for other soil organisms.

Earthworm burrows provide homes for insects and other soil organisms.

32. Describe the relationship between plants, animals, and the soil in an ecosystem.

It is the entire system of life and its environmental and geographical factors that influence all life, including the plants, animals, and the environmental factors.

33. Define soil management.

Practices used to conserve and develop soil.

34. List three factors affecting soil health.

Biological, mechanical or physical, chemical.

35. Compare/contrast the earthworm/s internal body structure to other agricultural animals.

The earthworm's internal structure is similar to the chicken's. The earthworm has a mouth but not teeth. Soil and food swallowed are pushed through the esophagus to a chamber, or sac, called the crop. The crop stores food for a short time. Then, the food passes into the gizzard. The gizzard has strong muscles which grind the food and are aided by tiny stones from the soil. Earthworms have five hearts.

36. Explain how tillage harms the soil and living organisms.

Tillage should only be performed when the soil is evenly moist. Tilling hard, dry soil breaks down the structure. Wet soil is heavy and easily compacted. Repeated tillage destroys a friable structure and minimizes aeration.

The Amazing Earthworm

An earthworm is not much to look at, and it is very little in the way of a brain. Yet its ecological significance is both great and far reaching.

In feeding, the earthworm breaks down plant and animal wastes. These wastes help improve the soil. Earthworms are nocturnal animals. The nightcrawler comes to the surface only after dark during which most of their feeding is done. It is hard to believe, but an earthworm has taste cells and shows a definite preference for certain foods. Try to feed them bits of fruit and different vegetable matter and see in what order they consume the food. Worms prefer food that is rotted. They also like oatmeal, cornmeal, chick starter, laying mash, and even coffee grounds. Earthworms are big eaters. In one acre of forest land, earthworms may eat ten tons of litter per year. In an orchard, they may eat 90 percent of the fallen leaves in three months.

The earthworm has a mouth but no teeth; therefore it cannot chew its food before swallowing it. Muscles push the soil and food the earthworm swallows through the esophagus into a chamber sac called the crop. The crop stores food for a short period of time; then the food passes into the gizzard. The gizzard has strong muscles which grind the food, aided by tiny stones from the soil that the earthworm has swallowed with it's food. This process is similar to the way chickens grind their food. The well ground food now passes into the intestine where special glands secrete juices to digest it. Some of the digested material is absorbed into the bloodstream and distributed to the earthworm's body; the rest passes out of the body as castings which is rich in nitrate, phosphate, and potash.

Decay of plant and animal tissue does not happen by itself. Decay is caused by many small forms of life, such as bacteria, mites, springtails, beetles, millipeeds, and earthworms. They feed on litter, which causes it to break down and release the minerals in a form plants can use.

In nature, most tillage is done by earthworms. They are earth's living plows and are at work in nearly all land areas. Although earthworms help improve soil, they cannot change really bad soil; as a matter of fact, they will not even live in it. If you dig out a piece of sod 12 inches square by 7 inches deep in good productive soil, you can find ten or more earthworms. Sufficient earthworm numbers proves to be a beneficial influence to the soil. If you find only two or three earthworms, the soil may not be right for them. Stocking it with new earthworms may be useless unless the soil is analyzed and improved first. Soils that have good earthworm populations is made even more productive by the presence of earthworms.

About 1,800 type of earthworms have been identified. One acre of good soil may hold between 50,000 to one million earthworms. Earthworms live in the top eighteen inches of soil, but some have been known to burrow as deep as eight or nine feet. Earthworms can move a stone fifty times their own weight. In clay and other hard packed soils, they find little or no space to wiggle through. In these type of soils, the earthworm burrows by swallowing soil, making it's own space. During one year, they may turn over forty tons of soil per acre.

Reproduction in earthworms is different. Both mates produce eggs that hatch into young earthworms. Each earthworm is both male and female. Each produces both sperm and eggs. However, most types of earthworms cannot fertilize their own eggs. Instead, they must mate so that the sperm form each other fertilizers the eggs. After mating, each worm produces a cocoon in which eggs and sperm are contained, thus allowing fertilization to occur. The cocoon also contains an egg white like material that serves as food for the young earthworms as they develop. Cocoons are left at or near the earth's surface.

Earthworm cocoon. Photo by Dr. Gaylan G. Scofield

Hatching of the cocoon takes place only when conditions are right. If the weather is mild and the soil is moist, the young earthworms may hatch in a few weeks. If the weather is hot, cold, or dry, hatching takes longer. Unlike earthworms, cocoons can survive dry or freezing weather. Each cocoon usually contains two to four young.

Although the earthworm's brain is tiny and primitive, it is very functional. "Intelligent" is not the word that best describes the behavior of the earthworm, and yet such a simple creature is capable of learning. An earthworm has no eyes or ears, yet it can hear very well and see all it needs to see. The skin contains light sensitive cells, most of which are either in the front or the rear of the animal. The earthworm is extremely sensitive to sound vibrations. Because of their well developed nervous system that contains a small brain and five hearts, earthworms are sensitive to touch.

An earthworm has no lungs, but instead, it breathes through the surface of it's body. That is why an earthworm's skin is moist and slimy. Oxygen is captured and dissolved in the skins moisture and then passed into the bloodstream. The earthworm's body is kept moist by glands that give off a thick liquid (mucus) which makes them feel slimy.

Earthworms probably do not lead very long lives. Apart from being eaten, they may fall victim to the sun or the cold. When in captivity, earthworms have lived for several year, but in their natural environment, most do not live past one year. Although natural enemies are numerous, earthworm populations are at little risk of devastation.

As we learn more about earthworms we come to understand their importance to the soil and our environment. Researchers and scientists are continuing to further their understanding of this important creature.

Feeding and burrowing, the earthworm goes about its life. But its existence and its way of life is vital to plants and soil. The earthworm is important to the human race.

Prepared by Douglas A. Wirth, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. November 1992
Edited by Dr. Gaylan G. Scofield, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. May 1993

Onsite Sample Evaluation & Comparison

Onsite research is not a new concept. For years researchers and farmers have sampled and compared all types of crops, fertilizers, and animals as a means of defining which line or strain works the best for their particular operation.

Although it is not new, onsite research is still a useful tool for monitoring and comparing various practices. Onsite sample evaluation and comparison (OSEC) can be used for determining nitrogen levels of soil, earthworm populations, and for the more traditional purposes of comparing different fertilizers, plant hybrids, and tillage practices.

Today, because of the introduction of new technologies and improved information communication systems, producers now know more about, or have greater access to information about process involved in production of plants and animals. Never before have we known so much about our soil and water resources, and how various production practices affect these vital resources.

For OSEC to be useful, not only for ourselves, but for others, we must ensure that the procedures used for data collection are unbiased (random), statistically reliable, and valid. Through education, we can introduce OSEC concepts for practical, everyday experiments.

In planning OSEC, consider only a single researchable question and determine the data to be collected. Choose the treatments that will allow collection of the data and then replicate (repeat) those treatments on a randomized basis.

OSEC can be incorporated comparing several concepts contained in the Living Soils curricula and is recommended for exciting, practical learning experiences for young people. Also it is suggested, and should be noted that certain experiences or comparisons may be combined to make more efficient use of field experience time.

One such area where OSEC can be used is in determining earthworm populations under different tillage practices. Refer to **LAB-SOIL-15** for the procedures in completing an onsite sample evaluation and comparison pertaining to earthworm populations.

Prepared by Douglas A. Wirth, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. November 1992.
Edited by Dr. Gaylan G. Scofield, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. May 1993.

Earthworm Population and Tons of Soil Processed Chart

Earthworms per sq. ft.	Earthworms per acre	Tons soil processed per acre /year	Earthworms per sq. ft.	Earthworms per acre	Tons soil processed per acre /year
1	43,560	5.23	45	1,960,200	235.35
2	87,120	10.46	46	2,003,760	240.58
3	130,680	15.69	47	2,047,320	245.81
4	174,240	20.92	48	2,090,880	251.04
5	217,800	26.15	49	2,134,440	256.27
6	261,360	31.38	50	2,178,000	261.50
7	304,920	36.61	51	2,221,560	266.73
8	348,480	41.84	52	2,265,120	271.96
9	392,040	47.07	53	2,308,680	277.19
10	435,600	52.30	54	2,352,240	282.42
11	479,160	57.53	55	2,395,800	287.65
12	522,720	62.76	56	2,439,360	292.88
13	566,280	67.99	57	2,482,920	298.11
14	609,840	73.22	58	2,526,480	303.34
15	653,400	78.45	59	2,570,040	308.57
16	696,960	83.68	60	2,613,600	313.80
17	740,520	88.91	61	2,657,160	319.03
18	784,080	94.14	62	2,700,720	324.26
19	827,640	99.37	63	2,744,280	329.49
20	871,200	104.60	64	2,787,840	334.72
21	914,760	109.83	65	2,831,400	339.95
22	958,320	115.06	66	2,874,960	345.18
23	1,001,880	120.29	67	2,918,520	350.41
24	1,045,440	125.52	68	2,962,080	355.64
25	1,089,000	130.75	69	3,005,640	360.87
26	1,132,560	135.98	70	3,049,200	366.10
27	1,176,120	141.21	71	3,092,760	371.33
28	1,219,680	146.44	72	3,136,320	376.56
29	1,263,240	151.67	73	3,179,880	381.79
30	1,306,800	156.90	74	3,223,440	387.02
31	1,350,360	162.13	75	3,267,000	392.25
32	1,393,920	167.36	76	3,310,560	397.48
33	1,437,480	172.59	77	3,354,120	402.71
34	1,481,040	177.82	78	3,397,680	407.94
35	1,524,600	183.05	79	3,441,240	413.17
36	1,568,160	188.28	80	3,484,800	418.40
37	1,611,720	193.51	81	3,528,360	423.63
38	1,655,280	198.74	82	3,571,920	428.86
39	1,698,840	203.97	83	3,615,480	434.09
40	1,742,400	209.20	84	3,659,040	439.32
41	1,785,960	214.43	85	3,702,600	444.55
42	1,829,520	219.66	86	3,746,160	449.78
43	1,873,080	224.89	87	3,789,720	455.01
44	1,916,640	230.12	88	3,833,280	460.24

Source: **ATTRA**, P.O. Box 3657, Fayetteville, Arkansas 72702. Phone (800) 346-9140.
Prepared by Dr. Gaylan G. Scofield, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. March 1992.

Earthworm Population Activity 1

Instructions

Using the information provided below, determine the number of earthworms per acre and the tons of soil processed per year per acre. What conclusions can you draw from the data and your calculations? (C=corn, B=soybean, O=oats, H=hay, M=meadow)

Earthworms/ft^2 x 43,560 ft^2/acre = Earthworms/acre

Earthworms/acre x .00012 tons soil processed/year/acre/worm = Tons soil/year/acre

Example:
10 earthworms/ft^2 x 43,560 ft^2/acre = 435,600 earthworms/acre
435,600 earthworms/acre x .00012 tons soil/year/acre/earthworm = 52.27 tons soil/year/acre

	Field 4 Sample 1	Field 6 Sample 1	Field 8 Sample 1	Field 9 Sample 1
Date	4/87	4/87	4/87	4/87
Earthworms/ft^2	44	8	13	17
Earthworms/ac				
Rotation ↓ = Sample	CBCO↓M	CBOMM↓M	↓CBOMMM	CBO↓MMM
Fertilizer	Manure	Manure	Manure	Manure
Cover Crop	Hay	Pasture	Rye	Pasture
Tillage	Spring Disk	Spring Disk	Fall Disk	Spring Disk
Herbicide	No	No	No	No
Tons Soil Processed per year/acre				

Conclusions

Source: **Thompson On Farm Research**, Dick & Sharon Thompson, Box 132, Route 2, Boone, Iowa 50036, (515) 432-1560
Prepared by Dr. Gaylan G. Scofield, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. February 1992

Earthworm Population Activity 2

Instructions

Using the information provided below, determine the number of earthworms per acre and the tons of soil processed per year per acre. What conclusions can you draw from the data and your calculations? (C=corn, B=soybean, O=oats, H=hay, M=meadow)

	Field 4B Sample 1	Field 4B Sample 2	Field 4B Sample 3	Field 4B Sample 4	Field 4B Sample 5	Field 4B Sample 6
Date	4/86	4/86	4/86	4/87	4/87	4/87
Worms/ft^2	13	13	10	59	48	44
Worms/ac						
Rotation ↓ = Sample	C↓B	C↓B	C↓B	↓CB	↓CB	↓CB
Fertilizer	NPK	NPK	NPK	NPK	NPK	NPK
Cover Crop	Hairy Vetch	Hairy Vetch	Hairy Vetch	Hairy Vetch	Hairy Vetch	Hairy Vetch
Tillage	Ridge Till 2 years	Ridge Till 2 years	Conven-tional 2 years	Ridge Till 3 years	Ridge Till 3 years	Conven-tional 2 years
Herbicide	No	Yes	No	No	Yes	No
Tons Soil Processed per yr/ac						

Conclusions

Source: **Thompson On-Farm Research**, Dick & Sharon Thompson, Box 132, Route 2, Boone, Iowa 50036, (515) 432-1560.
Prepared by Dr. Gaylan G. Sonfield, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. February 1992.

Earthworm Population Activity 3

Instructions

Using the information provided below, determine the number of earthworms per acre and the tons of soil processed per year per acre. What conclusions can you draw from the data and your calculations? (C=corn, B=soybean, O=oats, H=hay, M=meadow)

	Field 5B Sample 1	Field 7B Sample 1	Field 5B Sample 2	Field 7B Sample 2
Date	4/86	4/86	4/87	4/87
Earthworms/ft^2	46	90	31	28
Earthworms/ac				
Rotation ↓ = Sample	CB↓COH	C↓BOMMM	CBC↓OH	CB↓OMMM
Fertilizer	Manure	Manure	Manure	Manure
Cover Crop	None	Hairy Vetch	None	None
Tillage	Ridge Till 3 years	Ridge Till 3 years	Spring Disk	Spring Disk
Herbicide	No	No	No	No
Tons Soil Processed per year/acre				

Conclusions

Source: **Thompson On-Farm Research**, Dick & Sharon Thompson, Box 132, Route 2, Boone, Iowa 50036, (515) 432-1560.
Prepared by Dr. Gaylan G. Scofield, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. February 1992.

Earthworm Population Activity 4

Instructions

Using the information provided below, determine the number of earthworms per acre and the tons of soil processed per year per acre. What conclusions can you draw from the data and your calculations? (C=corn, B=soybean, O=oats, H=hay, M=meadow)

	Field 3N Sample 1	Field 3N Sample 2	Field 3N Sample 3
Date	4/87	4/87	4/87
Earthworms/ft^2	17	29	65
Earthworms/acre			
Rotation ↓ = Sample	↓ CB	↓ CB	↓ CB
Fertilizer	Compost	NPK	Manure
Cover Crop	Hairy Vetch	Hairy Vetch	Hairy Vetch
Tillage	Spring Disk	Ridge Till 3 years	Ridge Till 3 years
Herbicide	No	Yes	No
Tons Soil Processed per/year/acre			

Conclusions

Source: **Thompson On-Farm Research**, Dick & Sharon Thompson, Box 132, Route 2, Boone, Iowa 50036, (515) 432-1560.
Prepared by Dr. Gaylan G. Scofield, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. February 1992.

Unit I Evaluation

I. Match the following terms to the correct definitions.

1.	___	Actinomycetes	14.	___	Nutrient Cycle
2.	___	Aeration	15.	___	Organic Matter
3.	___	Burrow	16.	___	Permeability
4.	___	Castings	17.	___	Red Worm
5.	___	Cocoons	18.	___	Reduced Tillage
6.	___	Composting	19.	___	Setae
7.	___	Crop Rotation	20.	___	Soil Fauna
8.	___	Earthworms	21.	___	Soil Flora
9.	___	Integrated Pest Management	22.	___	Soil Organisms
10.	___	Microbes	23.	___	Soil Structure
11.	___	Midden	24.	___	Sustainable Agriculture
12.	___	Nightcrawler	25.	___	Symbiosis
13.	___	No-till	26.	___	Texture

(a) Living creatures so small they can only be seen through a microscope.
(b) The recycling and converting nutrients into a form usable for plants.
(c) Plant related soil organisms.
(d) Profitable cropping and livestock systems that will sustain the soil and water resources and maintain a quality environment.
(e) Providing small passageways for air to filter through the soil.
(f) The relative portion of the various sizes of particles (sand, silt, clay).
(g) Living creatures -- earthworms, microorganisms, insects -- that live in the soil.
(h) The way that soil particles are arranged together.
(i) The ease with which something can pass through soil.
(j) The living together of dissimilar organisms.
(k) An ecological approach to managing pests using pesticides only when and where necessary to reduce economic losses and minimize adverse side effects.
(l) Plant and animal remains at various stages of decomposition.
(m) The sequencing of crops, alternating each year so as to break up insect cycles and increase natural fixation of nitrogen.
(n) Animal related soil organisms.
(o) A group of microorganisms responsible for the earthy smell of compost.
(p) Earthworm tunnel.
(q) Waste product from earthworms.
(r) Contains baby earthworms.
(s) Maybe the most important creature in the history of the world.
(t) Serves as a lid to earthworm burrows.
(u) Biological degradation or breakdown of organic matter by a managed process.
(v) Large earthworm that burrows vertically.
(w) Smaller earthworm that burrows horizontally.
(x) Small hooks on the earthworm's body used to pull themselves along.
(y) Leaves at least 30% of residue coverage on the soil surface before planting.
(z) Planting without disturbing the soil.

II. Answer the following in detail.

27. Why is soil the earth's most valuable resource?

28. Why are earthworms an indicator of good soil quality?

29. Is the living soil as important in one part of the world as another? Why?

30. Explain the message contained in *The Earthworm Song*.

31. Explain how earthworms provide habitat for other soil organisms.

32. Describe the relationship between plants, animals, and the soil in an ecosystem.

33. Define soil management.

34. List three factors affecting soil health.

35. Compare/contrast the earthworm's internal body structure to other agricultural animals.

36. Explain how tillage harms the soil and living organisms.

Earthworm's Effect on the Soil - Lab Exercise

Introduction

Earthworms have a major impact on the soil. Through their burrowing soil drainage is increased and aeration is improved. Earthworms help release minerals that plants need by putting them back into the soil to be used again. Earthworms are also beneficial to lawns. They help prevent thatch buildup by feeding on it. Earthworms are very beneficial to home gardens through soil conditioning.

Objective

Participants will conduct a controlled laboratory experiment to observe and measure soil drainage and aeration.

Competencies

1. Analyze the environmental impact that earthworms have on soil.
2. Apply/use scientific methods/analysis.
3. Interpret and explain findings.

Materials

1. 4 5-gallon containers.
2. 30-45 earthworms (nightcrawlers).
3. Electric drill with ¼" drill bit.
4. Fertile soil to fill containers.
5. Earthworm food (dried manure, crop residue, etc.).
6. Grease marker.
7. Clean water.

Crop residue covering earthworm midden. Photo by Gary Huber.

Procedure

1. Drill 8-12 ¼" holes in the bottom of each bucket.
2. Fill each container with soil approximately 2" from the top.
3. Use the grease marker to number each container on the outside and mark the soil level on the inside wall.
4. Moisten the soil in each container with ½ gallon of water.
5. Add 10-15 nightcrawlers to containers 1, 2, and 3.
6. Add a different kind of earthworm food (manure, soybean stubble, corn stubble) to containers 1, 2, and 3.
7. Place the containers in a dark place since nightcrawlers feed at night.
8. Replenish the food supply as needed in each container.
9. Add additional moisture as needed to keep the soil from drying out completely. When adding water, use a brick or flat piece of material on which to pour the water to avoid soil compaction.

10. Observe the original soil level marked on the sides of the containers after a period of time (2-3 weeks). Also observe if there are any preferences of food types, water infiltration, and total volume of soil developed.
11. Other variations of this experiment may be conducted, including planting seeds in the containers and comparing growth, water absorption, and soil nutrient rates.

Conclusions

Prepared by Douglas A. Wirth, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. May 1993.
Edited by Dr. Gaylan G. Scofield, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. May 1993.

Earthworm's Effect on the Soil - Field Exercise

Introduction

Earthworms burrow as a means of getting to food or just to get to a different location. These burrows have an affect on soil structure. Different types of earthworms may burrow vertically and others burrow horizontally, and some do both. The extent of earthworm activity can be correlated to the soil infiltration rate. Earthworms prefer well-drained, fertile soils that contain plenty of organic matter, such as mulch and manure. Earthworm populations may be viewed as a visible sign of soil health, because conditions in which earthworms thrive are also good for other soil flora, fauna, and plant roots.

Objective

Participants will observe the effects earthworms have on the infiltration rates.

Competencies

1. Explain the impact earthworms have on natural resources and the environment.
2. Conduct an onsite experiment.
3. Apply/use scientific methods/analysis.
4. Analyze and interpret data to make sound management decisions.
5. Work effectively with others.

Materials

1. 2 55-gallon containers.
2. 30 gallons of water.
3. 50 nightcrawlers.
4. 200 red earthworms.
5. Sledge hammer, shovel, 4' plank, tape measure, grease marker.

Procedure

1. The best time to establish this experiment is early spring or early fall.
2. Remove the top and bottom of both 55-gallon containers. Cut each container into ⅓. **Follow safety procedures when removing top and bottoms of containers**.
3. Locate a suitable site for the experiment, crop field (corn or soybean), alfalfa field or pasture, lawn and garden, or continuous tillage and no-till.
4. Obtain the current soil survey from the local Soil Conservation Office to determine soil type and other needed information.
5. Place the 3 containers 30 feet apart and 6 inches into the soil. Use a sledge hammer and plank to drive the containers into the soil or a shovel to remove soil at the containers edge. It may be helpful to soak the container locations before driving into

the soil. If a shovel is used, avoid removing excess soil within the container.

6. Place the remaining 3 containers approximately 200 feet away, in the same soil type, adjacent to the first row of barrels.
7. Label each container (#1-A, B, C & #2-A, B, C).
8. Place 25 nightcrawlers in each container A and 100 red earthworms in each container B. Container C will serve as the control container.
9. Add residue from the surrounding area to each container. Keep the residue and soil within the containers moist to promote earthworm activity.
10. After a period of time (1-2 months) add 5 gallons of water to each barrel, recording the time and water level on the inside of each container with a grease marker. Observe and record the water level at regular time periods (every ½ hour). This process can be extended over a longer time period (3 months or more) to observe continued earthworm activity.

Conclusions

Onsite Sample Evaluation and Comparison

Introduction

In order to make reliable comparisons, it is important to select sites that are similar except for the one variable you want to compare. For example, the sites being compared should have the same crop rotation, fertilizer treatment, and soil type. The sites should also be the same in manure applications (both having had manure applied or neither having had it applied). The best time of the year to make comparisons is early spring after the frost has gone out or in the fall (September-November). Summer is not a good time as earthworms go deeper in hot weather.

Objective

Participants will compare earthworm populations in field settings.

Competencies

1. Analyze the environmental impact that agricultural practices may have on soil.
2. Compare farming systems for best long-term return results.
3. Use standard soil survey report.
4. Apply/use scientific methods/analysis.

Earthworm population count. Photo by Gary Huber.

Materials

1. Clean water.
2. 40% stock solution of formaldehyde.
3. Several 1 gallon containers with lids.
4. Shovel, garden fork, tape measure, wooden stakes, mallet, tweezers.
5. 6 wooden squares 12" x 12" or sheet metal squares 12" x 12" x 3".
6. County soil survey.

Procedure

1. Construct wooden or metal squares (metal woks best to retain sampling solution).
2. Prepare a .003% formaldehyde and water solution from 40% stock formaldehyde solution (25ml of 40% solution per 1 gallon of water). **Use prescribed safety measures when handling any chemical.**
3. Contact your local Soil Conservation Service District Conservationist and indicate your class wants to do a research project to compare earthworm populations. Explain that you are looking for two locations (fields) in close proximity to each other that are the same in terms of soil types and crop rotations, but are different in tillage systems being used (no-till vs conventional tillage). Ask for suggestions of operators or landowners who could be contacted.

4. Contact and visit with willing operators or landowners. Using a county soil survey, locate the two locations (fields) operated by the operator(s) or landowner(s) that have the same soil types, cropping histories, etc. Only one difference should occur between the sites (fields), such as the type of tillage system used. Locate smaller working sites within the two locations, both facing the same direction and in the same position on the slope (top, side, or bottom).
5. Interview the operator(s) and record the history information that is important for comparison. Record your information on the **Earthworm Count Recording Data Sheet**. Record those items that will insure a reliable comparison of information.
6. Identify the working sites on a map, with distances shown in reference to a landmark, which can be identified later in the year or in future years. File the location map with the recording sheets for future followup.
7. Once the working sites have been located, take multiple earthworm counts in a relatively small area. It is desirable to get six replications if statistical sampling is intended. Average the number of earthworms found in each count to arrive at one representative number. Where counts are taken in relation to the crop row makes a big difference. Population counts should be taken over the top of the row as earthworms will congregate in the roots. Two different methods of sampling may be used.

   Method #1

   A. Use a tape measure to mark a 12" x 12" square and place a wooden stake at each corner.
   B. Place depth control mark on the garden fork tines at the 7" level.
   C. Using the garden fork remove the soil from the 12" x 7" area.
   D. Carefully look through the soil and count the number of earthworms found.
   E. Determine the number of earthworms contained per acre and the amount of soil processed per acre per year. **(Refer to ACT-SOIL-15 or INFO-SOIL-13)**.
   F. Select other sites and repeat. Note the differences found at each site. Identify differences which may affect earthworm populations.

   Method #2

   A. Place the wooden square on top of the soil or the metal square ½" into the soil where the population count will be taken.
   B. Pour the .003% formaldehyde/water solution over the soil contained in the square until saturated.
   C. Take a population count after 10 minutes. Use tweezers to handle the earthworms.
   D. Determine the number of earthworms contained per acre and the amount of soil processed per acre per year. **(Refer to ACT-SOIL-15 or INFO-SOIL-13)**.
   E. Rinse earthworms with clean water and then release outside of the square.
   F. Select other sites and repeat. Note the differences found at each site. Identify differences which may affect earthworm populations.
8. Pour an equal amount of water on each working site and record time for the water to soak in or run off.

Conclusions

From your observations and study of Unit I, answer the questions and write your conclusions on the conclusion page. Submit the your conclusion page and data sheet(s) for evaluation.

Onsite Sample Evaluation and Comparison Conclusion Page

1. Explain the differences in soil structure at your working sites.

2. Were there any differences in numbers of other living organisms in addition to earthworms, and if so what kind, how many, and why?

3. Site #1 time _____ Site #2 time _____ Describe the differences and how this is important for erosion control and moisture conservation.

4. Summarize your conclusions from all observations and data collected. Address the following questions in your conclusion. Attach additional sheets if necessary. For additional data on tillage system comparisons, review research done by Mackay and Kladivko, Journal Paper #11,663, Purdue University Agriculture Experiment Station, reprinted from Rhizosphere Dynamics, American Association for Advancement of Science, ©1990.
    A. Do you have sufficient evidence to conclude there is a difference in earthworm populations in the two locations?
    B. Were the variable conditions for two working sites the same? If not, what was the difference and could this have an effect on the results? Why?
    C. What significance does your findings have in relation to the future of a productive agriculture and a quality environment?
    D. What do your results reveal?

Prepared by Eldon C. Weber, Department of Agricultural Education & Studies and Gary Huber, Iowa State University Extension/Practical Farmers of Iowa, Iowa State University, Ames, Iowa. May 1993.
Edited by Dr. Gaylan G. Scofield, Department of Agricultural Education & Studies, Iowa State University, Ames, Iowa. May 1993.

Earthworm Count Recording Data Sheet

Field Location (locate and record on soil survey) **Date of Sample**_____

Landowner _____ Field number _____ Site number _____

Soil type _____

Describe general working site conditions taking in consideration soil moisture, location on slope (percent of slope, direction of slope, and whether site is on top, shoulder, side, or toeslope).

Describe tillage system (when started and implements used by time of year and crop grown).

Crop/input by year since tillage system started.

Year								
Crop								
Anhydrous Ammonia								
Manure								
Insecticide								

Answer yes or no for anhydrous ammonia, manure, and insecticide.

Earthworm sampling method _____ Sampling duration if formaldehyde used _____

Sample Number	Number of Earthworms	Sampling Method	Location (relative to row, etc.)
1			
2			
3			
4			
5			
6			
7			
8			
9			

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ED 405 709

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